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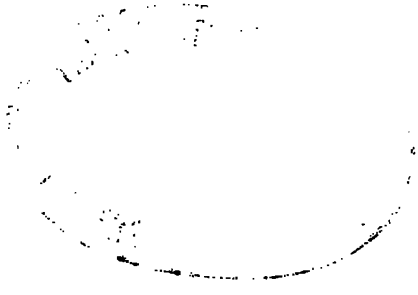


Rudolph & Leuzinger

SOUTTAR

ON

STREET TRAMWAYS.

STREET TRAMWAYS.

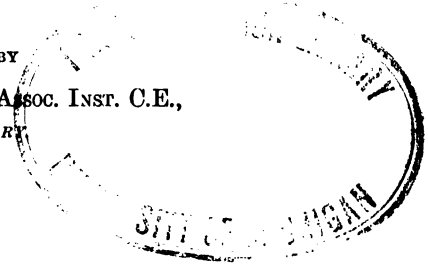
BY

ROBINSON SOUTTAR.

WITH AN ABSTRACT OF THE DISCUSSION UPON THE PAPER.

EDITED BY

JAMES FORREST, Assoc. Inst. C.E.,
SECRETARY.



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THE INSTITUTION OF CIVIL ENGINEERS.

SECT. I.—MINUTES OF PROCEEDINGS.

April 24, 1877.

GEORGE ROBERT STEPHENSON, President,
in the Chair.

No. 1,518.—"Street Tramways." By ROBINSON SOUTTAR.

PART I.—TRAMWAY CONSTRUCTION.

Foundation.—Where a tramway is likely to be subjected to heavy traffic, it will generally be desirable to excavate about 7 inches under the lower surface of the longitudinal sleeper, and to lay a bed of Portland cement or bituminous concrete over the whole width of the tramway. Some doubt has been expressed as to the value of cement concrete as a tramway base, from the fact that in many cases where tramways have been taken up, the concrete is found to have perished; but this is probably owing not so much to the vibration of the tramway as to the poverty of the concrete in the first instance. Tramways have frequently (from causes beyond the engineer's control) to be hurried to completion, and the concrete is attacked by paving beaters and street traffic before it has thoroughly consolidated. A bed of concrete 7 inches thick requires from two to three weeks to set throughout, whereas it is afforded sometimes hardly as many days. When it is necessary to hurry the work, it would mostly be wiser to use bituminous concrete, and this concrete will also be more suitable where the thickness is less than 6 inches.

Cross sleepers should be imbedded in the concrete, as they are of great value in preserving the level of the rails. The rails of the Birkenhead street railway, laid twelve years ago with cross sleepers, preserve their level better than some lines laid at a comparatively recent date without. Objections have, however, been urged against the use of cross sleepers on tramways. It is said that they injure the concrete by their vibration, and that the paving setts will not bed firmly over them. This is true, to some extent, of rectangular cross sleepers, but the objections will be overcome if cross sleepers with slightly bevelled sides are used,

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measuring, say, 5 inches on the top and 7 inches on the underside (Plate 1, Figs. 7–10). The concrete cannot fall away from bevelled sleepers, and if they are soundly bedded, and the concrete well punned round them, vibration would appear to be impossible. This being so, the paving will bed perfectly if care is exercised in selecting stone of a depth that will allow of a thin cushion of sand lying between the stone and the wood, and especially if the paving joints are grouted with pitch.

Longitudinal Bearing.—Tramways with rigid iron bearings have been constructed, and mention will be made of these hereafter. It is generally conceded, however, that a continuous timber bearing is an essential element in a perfect tramway. It forms a cushion which absorbs some of the sound and jarring, and renders tramway travelling agreeable and noiseless. It is also of service to the rail, doubtless increasing its life considerably as compared with what that would be if the rail was fixed on an iron bed. It is likely, too, that the elasticity of the timber bearing neutralises in some measure the vibration and hammering to which a tram rail is subject, and which but for the presence of this elastic medium would injure the concrete.

With regard to the life of the timber great misapprehension exists. The Author has taken up pitch pine, spruce, and memel, after it has lain five, six, and eight years, and found it to all appearance as good as when laid. He has also taken up timber which had been lying twelve years, and found it, where the line had been paved, in very fair condition. The timber referred to had carried a rail spiked through the groove, and the timber was in good condition only where it had not been injured by spikes or transverse saw cuts. In constructing tramways a pernicious practice still prevails of sawing the timber and driving wedges into the saw cuts so as to bend it round curves. When this is done the timber splits and rots quickly. Where the curve is so sharp that the longitudinal cannot be sprung round it, the timber should be sawn to template. If care is taken in these respects, the longitudinal will last fifteen to twenty years, even with the spiked rail. If the box rail (*i.e.* a rail having side flanges and fastened on the sides with wrought-iron dogs) is used, there will hardly be a limit to the life of the timber. As a matter of fact, however, it will be advisable to change the bearing when the rail is changed, as the timber will get torn in the operation, and the price of the longitudinal being insignificant, it will be better to have a fresh one with the fresh rail. If, therefore, the rail is calculated to last

twenty-five years, the timber, if sound, intact and properly creosoted, may be depended on to bear it as long.

Rail and Fastener.—When tramways were inaugurated in England by the laying of the Birkenhead street railway, the American section of rail was used (Plate 1, Fig. 1). Being unsatisfactory, however, it was removed, and a grooved rail, spiked through the groove, substituted. The grooved rail has been laid on every subsequent system, although alterations have been made on the underside and in the manner of fastening the rail. The spiked rail, as laid on the Birkenhead and other tramways (Fig. 2), has certain advantages. It can be taken off and changed when worn out without the paving being in any way disturbed. The plate-laying is done very readily, and the rails can be cut and scarfed with great ease. Where, therefore, cheapness at first is the chief consideration, a tramway laid with flat spiked rails will answer; but these have many disadvantages which render them unsuitable where there is much car or street traffic to contend with. The spiking is the weakest point. At first it was feared that the timber would not grip the spikes, and they were made in some instances to go right through and be screwed up with nut and flanged washer beneath. This was speedily found to be superfluous, as the spike-head wore away first. The spike-heads are worn off by the working of the rail, or are knocked off by the car, so quickly that this form of rail requires respiking once a year, or more frequently where the traffic is considerable. The spike-holes weaken the rail, and the spikes act as wedges, so that the rail is split in a few years; a rail $\frac{3}{4}$ inch thick under the groove lasting six years and upwards.

The spiked rail has been superseded by the box rail (Fig. 3). This has flanges on the underside, punched with holes 18 inches apart, alternately on the right and on the left. Through each hole one end of a stout clip is driven, the other end, which is jagged, being driven into the longitudinal sleeper. This rail answers well. The groove is no longer weakened by the fastener, neither is the fastener in any danger of getting injured or worn. Care must be taken to check the sleeper so that it will exactly fit the rail, to press the sleeper well home into the rail by hand-screws, and to see that the fastener is not cracked at the neck in driving. If these points are attended to a rail fastened in this way will never work loose. These clip fasteners, however, if applied to the ordinary form of rail, by projecting keep the stone immediately adjacent away from the rail, and as they occur very frequently, there being ordinarily fourteen thousand fasteners per mile of double

way, the evil is a substantial one. It is found, besides, that every wheel which strikes a hole helps to extend it, until by degrees an interstice is formed along the side of the rail, down which water soaks, washing the bedding from under the stone, and permitting it to sink beneath the rail-level. Anything therefore which prevents the stone from coming dead up to the rail is highly objectionable.

The Author has introduced a rail which seems to meet this difficulty (Plate 1, Figs. 7–10). The flanges are brought in beneath $\frac{3}{8}$ inch, that is, the thickness of the clips; and if a bit of the longitudinal sleeper is gouged out where the hole in the flange of the rail comes, the fastener can be driven in flush with the sleeper and the side of the rail. The paving setts can then be got dead up to the rail, which will thus be firmly gripped, and the tendency to form ruts alongside, which this fastener, excellent in every other respect encourages, is abolished. Not only so, but whereas there has been heretofore an inducement to keep the fasteners widely apart, so as to diminish the number of these holes in the paving, there is now no such inducement, and the number of fasteners can be increased to any extent without the introduction of a single disadvantageous feature.

The changing of tram rails when worn out is such an expensive matter, and a few lbs. per yard is of so little consequence in first cost, that it is always better, whether the traffic to be sustained will be little or much, to lay a good stout rail at the outset. The first tramway rails laid in this country weighed rather more than 40 lbs. per yard; but the weight has been increased, and 60 lbs. is now considered the best weight for rails where the traffic will be great. At present prices it will be more economical to use Bessemer steel instead of iron for the rails. In Liverpool it is proposed to use a rail having a centre groove. Whether experience will justify this departure from precedent remains to be seen. It is to be feared that the friction will be greater, owing to there being no escape for mud and gravel; that the tendency of cars to run off on curves will be greater, and that the centre flanges on the car wheels will be weaker, and more liable to chip off than the side flanges.

Paving.—The paving of a tramway is a most expensive item, amounting to about one-half the entire cost; but it is impossible to avoid this expense. The stone abutting against the rail supports and protects it, and without it the rail would be shaken loose, forced out of gauge, and hammered to pieces by the ordinary street traffic. The attempt has been made to provide this protec-

tion economically, by placing a row of setts on each side of a rail, and filling between with macadam. It is, however, impossible to maintain the narrow strips of macadam at the same level as the setts, and the road soon gets into a rough state. The inconvenience to the public is equalled by the inconvenience to the tramway company, whose horses, running upon the uneven road with one foot on stone the other on macadam, will stumble and fall lame daily. On this point engines would have the advantage over horses. Asphalt has been tried as a pavement for tramways, but has proved a complete failure, and has in most instances been replaced by stone. Superficially speaking, it would appear to have advantages. It can be laid with neatness and uniformity from rail to rail, and makes at first a very close joint with the rail. The slight vibration to which a tram rail is subject soon frees it from the asphalt, which then exposes alongside each rail two edges, and as asphalt seems to be specially weak at its edges, it is soon ground into holes and ruts. So far as wooden pavement has been tried it has scarcely given more satisfaction. The wear along the rail side is so great that nothing but hard stone will support it. If any other material is used it should be looked upon as an expensive luxury, and the cost of repair should be borne by those for whose benefit the luxury has been provided. Looked at in this light, the Improved Wood Pavement Company's system is probably the only one at all suitable, as the longitudinal sleeper could be fastened to the boarding in a way which would keep the setts and rail at one level until the former were fairly rubbed away. Where the gradient of the street renders hard stone unsuitable for the traffic, it will sometimes be best to let the rows of setts immediately abutting on the rail be of a hard nature, and to pave between with a less slippery stone. The joints of the paving should be racked with dried shingle and grouted with pitch. This impervious pavement is of special value on a tramway, as the rain-water flows down the rail, and (unless the joints are sealed by pitch) sinks down by the rail side, causing the setts to present a ragged appearance, and washing away racking and bedding. Excessive ramming should not be permitted where the tramway has been well concreted, as the concrete will be greatly injured. It will be necessary to tap the stones lightly with the rammer, so as to shake the shingle into the joints, but nothing beyond this should be allowed. The stones alongside rails should be picked, care being taken to see that they can come dead up to the rail, that they are exactly the depth from rail to

concrete, so that they may never sink beneath the level of the rail, and that they break joint well with one another.

Points.—Points were at first made wholly of cast iron, flat, about 6 feet long, and spiked through the groove. Soon side flanges were introduced, and gradually it has been found desirable to lengthen the point, so as to make it easier, until 9 feet has come to be the favourite length where the rail is 4 inches wide. The points wear rapidly at the end of the tongue, where the wheel of the car bears only upon a small portion of the tread. Under heavy traffic a point will wear greatly in this place in twelve months; but the point will not thereby become unworkable, and where appearance is not much object it will last two years. Chilled iron gives somewhat better results, but there is not much difference. A good plan is to insert two pieces of cast steel, one in the tread and one in the tongue. These are securely riveted to the cast iron, which has a recess for the steel, and a projection, which, serving as a back, prevents the steel from being knocked out of position. A point so constructed should last three years. The same idea may be ingeniously varied, by making the steel in one piece, bevelled in front and secured by a pin behind, so that it may be taken away when worn out and replaced by a new piece, without the point being disturbed (Fig. 14). This last is probably the best point yet designed. In movable points the tongue should be made of one piece of steel, and not of steel and iron welded together.

Crossings.—Crossings were at first made flat and spiked in the groove. They were found to wear out and snap across quickly. They were then cast with side flanges, and in this form they wear better, but are still unreliable. Besides, curves in tramway work are so various, and sometimes of necessity so sharp, that it is far from easy to keep a stock of crossings in hand sufficient to maintain an existing tramway, and very troublesome to model with sufficient accuracy patterns for a new one. Consequently, where cast-iron crossings are used, curves have frequently a broken-backed appearance. It is better to lay the rails throughout with all necessary curves, and then, having marked the places where the rails cross, cut or saw them with the proper bevel. In laying crossings the longitudinal timber and rails should be made to break joint, the scarfed timber being bridged by a continuous rail, and the scarfed rail lying on a continuous timber. Thus, in Fig. 11, it will be better to lay the straight timbers A A than the curved timbers A B, scarfing these at crossings. The curved rails

should then be laid running continuously through and bridging the scarfed timber; and, finally, the straight rails should be cut and laid on the continuous timber A A. This method entails extra labour, but it is impossible to keep the scarfed rails and the continuous rails at the same level unless it be so carried out.

Curves.—The question of curves is still misunderstood in tramway work. It having been found that cars can be hauled round almost any curve, little care is taken to lay easy curves. This is a great mistake. On a sharp curve the cars will get wrenched, the horses strained, and the passengers occasionally injured. Where there is any choice the curves should not be sharper than from 150 to 200 feet radius. The Author was surprised to see plans for an important system of tramways where it was proposed to construct passing places with curves of 60 feet radius, and room for one car only; whereas all experience shows that passing places should have room for two cars at least. Cast-iron rails have been used for sharp curves, but they wear and break quickly. Flat rails are also used, the idea being to let the wheels take their natural course, one slightly outside the other. But on very sharp curves, where flat rails would appear to be most necessary, they, having no groove wherewith to catch the flange of the wheel, permit it to leave the rails. On sharp curves, where cars had the habit of running off, the Author has frequently had to take up flat rails and lay grooved rails. The proper course would be to roll rails with greater grooves for use on curves; but this would be expensive, and is unnecessary. Wrought-iron rails can be bent to any curve over 30 feet radius by the "Jim Crow." Steel rails had better be at least partially bent at the rolling mill.

Single Line.—Single line may be loop line, whereby the up car traverses one street the down car another, or single line with passing places. Where the streets traversed by loop lines are more than a trifling distance apart loop lines are most objectionable, as it is found that though the through traffic from the point where the lines diverge to the place where they again meet is secured, the local traffic along either single line remains undeveloped. If residents can only depend on a car one way, they will not depend on the car at all. It is easier to develop local traffic upon a single line with passing places, than upon a loop line; nevertheless, the former still labours under grave disadvantages. The ideal tram car will glide along swiftly and noiselessly, a constant temptation to the foot passenger. On a double line this may be, but on a single there is inevitably so much delay that the cars, instead of being a

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to be often renewed." Though the timber bearings first laid in this country were, from inexperience, laid under a spiked rail, and often in a way which did not give the timber a fair chance, the Author is not aware that the timber of any tramway in the kingdom has been or is being renewed from any fault in the timber. He is connected with the two oldest tramways in the kingdom—severally eight and twelve years old—and can certify that the timber of neither has been renewed. The Authors of the book in question have perhaps been deceived by having observed the work of laying box and discarding flat rails, which is now being proceeded with by degrees wherever tramways had the disadvantage of being laid with flat rails in the first instance. As these wear out, box rails with side fastenings are substituted; and as the deep flanges of the box rail require a corresponding rybat on the timber, it is evident that the timber must be changed with the rail. Mr. George Hopkins, an authority on tramway construction, says: "I have frequent occasion in the course of alterations to take up sleepers that have been in use seven years, and I find the timber perfectly sound."

The third argument is, "owing to its (timber) yielding nature, and to the fact of the sleepers being frequently deflected by passing loads, the fastenings of the rails work loose, and the difficulty of securing them is much increased." The Author admits this with regard to the old spiked rail, but he has not known any instance of a box rail properly side-fastened working loose. Where he has found a loose rail it has been because the sleeper had not been pressed into the rail, or the side fastenings had been omitted or been broken by careless driving. It is evident that the firmness of this rail is simply a question of the number of fasteners, and, confined and kept tight to the sleeper as these are by the paving, it will be seen that they cannot possibly work loose. If the hole punched in the rail flange be slightly larger than the head of the fastener, it is evident that the rail will work up and down under varying pressure without the fastener being disturbed in the slightest degree.

So far, therefore, experience in tramway construction seems to prove:—1st. That the timber sleeper, by its elasticity, acting the part of a cushion for the rail and a buffer for the concrete, occupies a valuable position, but that this elasticity is not so great as to affect the paving in any way; 2nd. That the timber sleeper, if laid with proper precautions, neither decays nor requires renewal, but will last whatever reasonable time the rail may be estimated to serve—say, from twenty to twenty-five years; 3rd. That the rail

may be secured to any desired extent by simply increasing the number of side fasteners, and that these may be fixed in such a manner that they will neither wear nor break, but hold good as long as the rail endures.

The experience of iron tramways in this country is limited to one system, which has been laid in various provincial towns. The rail is supported on cast-iron chairs placed 3 feet apart (Figs. 5 and 6). The earlier specimens were spiked through the groove, the spike going into a hard wood pin in the top of the chair. An improvement was made by the introduction of a side fastener somewhat similar to the one already described, the lower end being driven into a hard wood plug in the side of the chair. This system lacks advantages in fastening which the timber sleeper possesses. In the latter case both ends of the fastener penetrate into the wood, and the fastener therefore never springs out; in the former the upper end simply catches the rail, and must be apt to spring out. All the power of screw and lever are used to press the timber into the rail before the fasteners are driven home; and the wood, when relieved from this pressure, has a tendency to spring back, and thus the fasteners are made doubly tight. Of course this cannot be done where wrought and cast iron are in question. Further, the fasteners must be opposite one another, with iron chairs, instead of alternately as in timber, and the number of fasteners cannot be increased unless the chairs are increased.

It is proposed to construct the Manchester tramways with a continuous cast-iron bearing, to which the rail is held by iron pins (Fig. 4). It is to be feared that the difficulty of constructing this system (entailing as it does getting the holes in the castings and the holes in the rails to correspond with delicacy) will be great, especially at curves and crossings; and that the rail will wear away more quickly on an iron bearing than on timber. Though it is possible that in a foreign country, where timber might be subjected to the ravages of insects, the iron tramway would be the only alternative, it is not easy to see what good purpose can be served by laying one in this country. An iron tramway must be expensive in the first place, troublesome to lay with accuracy, and most unmanageable when out of repair. It is not at all likely that an iron bearing, such as that proposed for Manchester, will last as long as a timber bearing, as there will be great wear at the fastenings; and even if it could be proved to be everlasting there would be little advantage, as the first cost would provide a fresh timber bearing every few years.

Part II.—Mechanical Motive Power.

In the year 1873 a Select Committee of the House of Commons took into consideration the working of Locomotive Engines on Roads, and in their report recommended the following (p. x):—"That self-contained locomotive carriages (or engines), not exceeding 6 tons in weight, making no sound from the blast, and consuming their own smoke, be classed as light, and that they be permitted to travel at the ordinary speed of vehicles drawn by horses, and only subject to the same restrictions as such vehicles." Before this date a law limiting the rate of speed to 2 miles per hour in towns was in force; and though various engineers had worked at the subject, and had discovered many of the difficulties that would have to be overcome in applying steam to tramways, practical men had generally hardly considered it worth while to spend time and money in working out an invention of which the legislature practically prohibited the use. Latterly, however, great energy has been shown in several cases with most encouraging results.

The difficulties which have to be surmounted in the invention of a tramway engine are so numerous that the railway locomotive is a simple affair in comparison. In the latter case power and endurance are the principal features; in the former much beside that is necessary.

Messrs. Hughes, of Loughborough, the inventors of a steam car which is at present regarded with favour, put the peculiarities of a tramway engine very fairly as follows:—1st. It must possess sufficient power to draw one or more loaded cars up steep gradients; 2nd. While possessing sufficient weight to grip the rails, especially on steep ascents, it must at the same time not be so heavy as to press injuriously on the rails; 3rd. It should possess very powerful brakes, so that it can be stopped almost instantaneously in a crowded thoroughfare; 4th. It must be so contrived as to take the curves which exist on all tramways easily; 5th. It must not emit its exhaust or any steam into the air; 6th. It must be smokeless; 7th. It must not produce any noise in working calculated to alarm timid passengers and horses; 8th. Its machinery must not be visible, and yet must be easily accessible; 9th. Its fire must be concealed, especially at night; 10th. It must not present an unsightly appearance; 11th. It must not require more than one attendant to work it; 12th. It must be reversible,

i.e. capable of going backwards or forwards with equal safety; and 13th. If possible, it should be so simple in construction and working that it can be driven by an unskilled man.

When these, which may be termed the external difficulties, have been met, then many internal difficulties, at present only guessed at, will arise, and though it is not contended that these difficulties are insuperable, still there is much to be accomplished before other than animal power can be used extensively on tramways. Neither is it desirable that the change, if change there is to be, should be unduly hastened, lest by the introduction of imperfect engines public prejudice, at present dormant, should be again aroused.

The tramway engines hitherto experimented with at all successfully have been of three classes:

1st. Steam engine and car in one, as Grantham's.
2nd. Steam engine separate from car, as Hughes' and Merryweather's.
3rd. Pneumatic car and engine in one, as Scott Moncrieff's and Mékarski's.

There is some difference of opinion as to whether it is more desirable to have the engine and car combined or separate, and substantial arguments may be urged on both sides. It is argued, on the one hand, that with a detached engine there must be a great deal of shunting at the beginning and end of the journey, and with tramways as at present laid this argument is very forcible; the Author having witnessed experiments where the changing of the engine from one end of the car to the other was a most tedious process. But the difficulty could be overcome to a great extent, in some cases by laying a circular line at the terminus, in others by a V shunt up a side street, and where neither is practicable by double cross-overs. Again, with a detached engine the difficulty of passing round quick curves is increased. It is likely that on a curve, say of 40 feet radius, the car would be occasionally pulled off the line. This objection is valid where quick curves are essential, but in many cases tramway curves are unnecessarily quick, and if mechanical motive power is introduced the tramway constructor must meet the difficulty by making the curves as easy as practicable. In the matter of adhesion, the detached engine is evidently inferior to its rival. Where the car and engine are combined it will not, probably, matter much how great the load on the car is, as the adhesion will increase in proportion; whereas

if the engine is separate, the weight it can pull after it will be a known quantity, and will be just that portion of the whole tractive force which is more than sufficient for itself.

On the other hand, the detached engine entails less alteration to rolling stock, and permits of two cars being drawn by one engine on special occasions. The design of engine and car combined must be greatly cramped; the separate engine can be designed with greater freedom, and in it the experience gained in connection with railway locomotives can be more fully taken advantage of. Though it is claimed for the Grantham steam car that the boilers are perfectly safe, and that the passengers experience no disagreeable sensation from the heat, it is to be feared that this state of things will not improve as the car becomes older, and it will be a long time before timid passengers will sit beside a boiler with complacency. Where detached engines are employed a smaller stock of engines will do the work, as in case of accident to the car, it can be unhooked and another attached. Where engine and car are combined a trifling accident will cause £800 to lie idle. In the matter of repairs generally the detached engine will be greatly superior to the combined. In the former case the engine can be removed at night and cleaned or repaired in a suitable engine shed; in the latter, the fittings of the car will be quickly soiled and damaged by the smoke and dirt incidental to engine repairs and cleaning.

From these considerations it is likely that detached engines will be used more generally than combined. At least this will be the case where steam is used. With compressed air the case is different. The machinery necessary to drive a car by compressed air is comparatively simple, and can be accommodated under a passenger car in a manner neither dangerous nor disagreeable to the passengers. This seems satisfactorily proved by Mr. Scott Moncrieff's car. If heating is resorted to, as in M. Mékarski's, it becomes a question whether the detached engine will not again be more suitable.

1. *Steam Engine and Car combined.*—The steam carriage designed by the late Mr. John Grantham, M. Inst. C.E., is slightly longer than an ordinary car, and has two boilers, so placed on each side in the centre of the car, that a continuous passage is maintained throughout for passengers. The driving wheels are of a larger size, and there are four smaller wheels on a bogie frame. The car can be driven either way and from either end, and is well under the driver's control. It complies with the Board of Trade regulation, which renders it necessary that the speed should be limited

by automatic machinery to 10 miles per hour. A stoker is required, and the objection caused by the escape of smoke and steam is not entirely abated. A Grantham steam car is at work on the Wantage tramway. It weighs empty 6½ tons, and when fully laden with fuel and passengers over 12 tons. It cost £800.

2. *Detached Engines.*—Messrs. Merryweather and Co. have many engines at work, chiefly on the Continent. Those used in Paris weigh, when laden with fuel and water, about 3⅛ tons. The boilers are multitubular, 6 feet long and 2 feet 6 inches in diameter. The two cylinders have a diameter of 6 inches, with a length of stroke of 10 inches. The working pressure is about 100 lbs., and the consumption of fuel 20 lbs. per hour. Each engine has ordinarily attached a car containing, when full, forty-eight passengers, which it draws up various ascending gradients, the steepest being about 1 in 30. The engine is perfectly under control, and can be propelled at any required speed at the will of the driver. The brake power is a foot brake, which acts on all the wheels at once with rapidity and effect. Various ingenious contrivances can be applied to these engines for increasing adhesion and power on heavy inclines. The exhaust steam from the engine is disposed of partly by condensation, viz. by mixture with dry air, by passing through diaphragms of wire gauze, and through a surface condenser; the residue is led into the smoke-box, and escapes in a superheated state. The speed of the engine is controlled by a governor, driven by the rotation of the wheels and acting upon a throttle valve. In the course of experiments on the Vale of Clyde tramways, it was found that, notwithstanding the apparent completeness of the methods for getting rid of the smoke and steam, the escape was still somewhat objectionable. The manufacturers believe they will be able to improve the engine in this respect, and it is to be hoped they will be successful, as no engine has a chance of succeeding in this country which renders outside travelling impossible or even disagreeable. In Paris a stoker accompanies the engine, but as it seems that his chief duty consists in blowing a horn, Messrs. Merryweather think his services might be dispensed with in this country. It is desirable that, on a tramway engine, not only the stoker, but the operation of stoking during the journey should be unnecessary.

The steam tramway engine designed by Messrs. Henry Hughes and Co., of Loughborough, is at present giving great satisfaction. It is heavier than Messrs. Merryweather's, weighing 4 tons 15 cwt. empty, 6 tons loaded. The cylinders are 7 inches in diameter,

with a length of stroke of 12 inches. The wheels are 24 inches in diameter, and coupled. The exhaust steam is got rid of by condensation. The condenser is subdivided by horizontal perforated partitions, down which a stream of cold water gradually falls, condensing during its descent the ascending currents of steam from the exhaust ports. The water of condensation is allowed to flow on to the road; or when this is objectionable, to accumulate in a tank under the tramway carriage, from which it is discharged at the end of the journey. Coke is used as fuel, and the amount of smoke and steam that issues from the roof of the engine is trifling, certainly not enough to annoy passengers. The firing of this engine is completed before it starts on its journey, and is not disturbed until the journey is complete. In this way much nuisance is doubtless saved, and the services of a stoker are rendered unnecessary. Messrs. Hughes endeavoured so to arrange their engine, that all the work requiring technical knowledge could be done before the engine started on its journey, and thereafter the engine could be driven by one, and he an unskilled, man. This principle has certainly been carried out, the engine being so constructed that the driver can perform every required service on ordinary occasions without moving from his seat in front. On the level, and on gradients as steep as 1 in 30, this engine can do all that would be required of a tramway engine sufficiently well; but on gradients of greater inclination than 1 in 30, the Author thinks that neither this nor any other engine he has seen could be trusted to stop with a laden car behind it, and to start again without trouble and delay. Still it is not right to draw absolutely adverse conclusions from this opinion. In actual practice it would not be necessary to stop an engine on a stiff incline unless it was a long one. On a well-managed tramway the horse cars would not be stopped under similar conditions. Though there are tramways that could not, owing to their gradients, be worked successfully by steam power, there are in a majority of cases no insuperable engineering obstacles. At the same time, it will probably be longer than some imagine before steam engines will be allowed to run to any considerable extent in towns.

3. *Pneumatic Cars.*—A pneumatic car, designed by Mr. Scott Moncrieff, has been at work on the Vale of Clyde tramways for some time. The car is in appearance like an ordinary passenger car, but the floor is more elevated. Under the ends of the floor three reservoirs, 6 feet long and 2 feet in diameter, are placed, and these, when charged, contain 100 cubic feet of air at a pressure of

350 lbs per square inch. The machinery lies between the reservoirs, under the middle of the car. Mr. Scott Moncrieff says, in a description of the car, "The principal obstacle with which inventors have had hitherto to contend in utilising compressed air at high pressures is the excessive cold that is produced in the exhaust, and this has proved fatal to all applications of compressed air for locomotive purposes up to the present time. In any mechanical arrangement, such as a locomotive carrying a definite quantity of compressed air, and absent from time to time from the original sources of supply at the pumping stations, it is absolutely necessary that the fullest advantage should be taken of the limited power stored in the receivers. The only way in which this can be done is by using the air expansively, and as the pressure is always decreasing towards the end of the journey, this expansion must vary correspondingly.

"By an arrangement of valve gear suited to these requirements, the air is always exhausted in the Scott Moncrieff system at the atmospheric pressure, the effect of which is not merely to obviate the difficulties arising from excessive cold, but also to propel the car in silence, and utilise to the utmost the available power."

It is impossible to judge fairly of the value of Mr. Scott Moncrieff's car under the circumstances presented on the Vale of Clyde lines. The car there is the first, and is, as might be expected, roughly constructed and unnecessarily heavy. The pumps for compressing the air are of a temporary character, and there is no proper storage for the air, so that the process of charging is exceedingly tedious, occupying an hour each journey. Under these circumstances it is rather remarkable that the car should have achieved even a degree of success, and been able to compete not discreditably with steam cars. Mr. Moncrieff is now building a new car of a larger size, and with greater capacity for storing air, and as he will be able in this car to take advantage of the improvements that experience has suggested, it is likely that even more satisfactory results will be arrived at.

M. Mékarski, of Paris, is the inventor of a tramway engine and car combined, driven by compressed air heated before admission into cylinders.[1] The reservoirs, thirteen in number, are cylindrical, and lie crosswise under the floor of the car. They contain when charged 70 cubic feet of air at a pressure of 375 lbs. On the front platform stands a vertical vessel filled with water at a high tem-

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xliii., p. 383, and vol. xliv., p. 254.

perature. The compressed air enters at the underside of this vessel, and bubbles up through the water, thus becoming charged with vapour. By a reducing arrangement the air can be admitted into the cylinders at any required pressure. From this car very good results are said to be obtained. The method, however, appears complicated, and the position of the hot-water vessel makes it necessary that the car should travel one way only. The weight of the car must be considerable, and it is possible that when compressed air is proposed to be used in this way, it will be found better to have a detached engine.

Part III.—Financial.

The cost of tramways is affected by so many circumstances that it would only be misleading to attempt to give an estimate. The price will vary from £1,500 to £6,000 per mile of single line, according to the design recommended for the particular road to be traversed and the price of materials at the time and place. A Table is annexed (p. 26) showing, as fully as practicable, the present position and progressive development of nine tramway companies. This Table attests the remarkable success achieved by tramways in this country within a few years. From it almost any information that can be desired on the subject of working expenses may be easily procured.

It is not easy at present to make any reliable comparison between the relative cost of horse and steam power on tramways. If attempted, it would be sure to err in favour of steam, from the fact that while experience has taught the worst that can be learned about horses, as yet the best only has been seen of engines. Where steam is introduced there will probably be a substantial saving, but less than the advocates of steam locomotion predict. The wear and tear to engines by mud getting amongst the gearing, sudden stoppages, collisions, jerking over stones in the groove, and running off lines, would be enormous. The repairs will entail the services of a staff of engine-fitters, and after a few years, when the engines become worn, workshops with expensive machinery and manned by expensive men will have to be erected. The nightly cleaning of the engines will be formidable, and can only be satisfactorily accomplished by skilled men. Horse-driving requires little skill, and it is easy to find drivers who will work long hours at a low rate of wages; but engine-drivers will require high wages, and will most likely decline to work twelve to thirteen hours per diem. Indulgence granted to drivers in this respect would have

to be extended to conductors, and in this way complication and expense would arise. It is to considerations such as these that the hesitation to recognise the value of a change from horse to steam power is to be attributed, rather than to prejudice.

In the following memoranda the actual cost of working a car by horses is contrasted with the probable cost of working by steam and air. The cost of fuel for steam power is taken from recorded experiments. The cost of fuel and fixed machinery in the third estimate is taken from Mr. Moncrieff's statement. In such matters as wages, repairs, cleaning, spare engines, &c., the Author has followed his own judgment, and the figures are somewhat higher than ordinary, but in practice they would probably be low enough. The wages of the engine-driver are taken as higher than the car-driver's wages. Most inventors claim that their engines can be driven by an unskilled man, and though this may be correct, it would be none the less extremely injudicious to trust unskilled men with them. One cleaner is allowed to every three engines. Such expenses as management, rent, interest on outlay, &c., are not included, as these would be about the same in any case. The spare engines are taken at 25 per cent., and, considering accidents and periodical overhauling, this number would not be excessive. It is always to be remembered, however, that whilst the cost of horse power has been ascertained with absolute certainty, the cost of mechanical motive power is, to some extent, an unknown quantity.

ESTIMATE No. 1.—COST of HORSE POWER per DIEM.

	£.	s.	d.
Forage for ten horses and one spare horse at 2s.	1	2	0
Veterinary attendance and shoeing	0	2	2
Depreciation of horses	0	6	3
Harness maintenance, renewal, and cleaning	0	1	1
Horsekeeper 3s. 6d., car-driver 5s., conductor 3s. 6d. . .	0	12	0
Per diem	2	3	6

Or assuming 60 miles per car per diem = 8¾d. per mile.

ESTIMATE No. 2.—COST of STEAM POWER per DIEM.

	£.	s.	d.
Fuel, oil, and water, 1d. per mile	0	5	0
Renewal of engines, 10 per cent..	0	3	3
Repair of engines, 1d. per mile	0	5	0
Interest on 25 per cent. spare engines	0	0	4
Engine cleaner (⅓) 1s. 6d., driver 6s. 6d., conductor 3s. 6d.	0	11	6
Per diem	1	5	1

Or at 60 miles per diem = 5d. per mile.

Where a stoker is necessary the rate would be 5¾d. per mile.

ESTIMATE No. 3.—COST of PNEUMATIC CAR per DIEM.

	Pence per Mile.		£.	s.	d.
Enginemen and firemen for fixed engines	0·125				
Depreciation of fixed machinery . . .	0·125				
„ cars	0·625				
Fuel, oil, &c.	0·500				
Contingencies	0·272				
	1·647	× 60 =	0	8	3
Repair of car engine 1*d.* per mile			0	5	0
Interest on spare engines			0	0	4
Cleaner ($\frac{1}{3}$) 1*s.* 6*d.*, driver 6*s.* 6*d.*, conductor 3*s.* 6*d.* . .			0	11	6
Per diem			1	5	1

Or at 60 miles per diem = 5*d.* per mile.

PART IV.—TRAMWAY CARRIAGES (Plate 1, Figs. 15 to 20).

The cars for the New York and Harlem street railway were built in 1832 by Messrs. John Stephenson and Co., of New York. These cars had the features of ordinary road coaches, viz. a carriage part independent of the body, elevated driver's seat, side-doors, and leather springs.

Springs.—The wear of the lower part of this description of vehicle proved to be so great, that it was soon found necessary to unite the carriage part to the underframe, to place the springs under the body, and to substitute steel for leather. At first the axle-box was fixed to the spring on the underside; but this was unsatisfactory, the adjustment of wheels and axles not being positive; and the single pedestal, which permitted the car to move in a vertical plane only, was introduced. In 1858 a further improvement was made; a yoke being placed on the axle-box, each end of which yoke sustained a spring, thus giving two springs to each journal. At the same time steel spiral springs were introduced; and these, in turn, gave way to india-rubber, which last are now almost universally used. The rubber is prepared in a way which makes its elasticity practically independent of temperature, and increases its power of sustaining burdens. The india-rubber springs are cheap, durable, easily changed, not liable to sudden failure like metal springs, and give ease and delicacy to the motion of the car.

Wheels (Figs. 21 to 25).—Much ingenuity has been expended in

designing car wheels. Solid wooden wheels, with steel or wrought-iron tires, were popular in England; but they are complicated; the tires are liable to work loose, and the endurance of the wheels does not justify their cost. Wheels with wooden spokes were attempted, but speedily abandoned. Light wheels, with cast hub and rim and wrought-iron spokes, are made and used in America, but they require great care in manufacture, and are costly. Crucible-steel wheels, cast in one piece with arms, are made in Sheffield. They are light, and seem to give good results. Wheels made of American chilled iron are, however, perhaps the best for the purpose. Where lightness is an object, as in the case of one-horse cars, openings are left between the arms. Of the American, the waved-plate wheels, manufactured by the Lobdell Car Wheel Company, give great satisfaction (Fig. 21). The difficulty in the manufacture of chilled wheels is, to combine strength in the plates, with sufficient depth of chill in the tread to insure durability. If the plate is flat, it is frequently injuriously affected by the sudden cooling of the outside rim; but the waved plate can give slightly, and is not left in a state of tension. The average life of chilled cast-iron wheels in America is from sixteen to eighteen months; but in England it is not more than ten to fifteen months, owing to the section of the rail. In America there is no groove, and the flange of the wheel has always plenty of freedom, and can only wear on one side. In England the groove is so narrow that the wheel flange is continually rubbing either on one side or the other. Stones are also caught by and forced into the groove, and the wheels get jerked and chipped. Nothing of the kind can happen with the American rail.

It is not an uncommon theory that wheels on the same axle, having the freedom of independent motion, will operate better than wheels fast on the axle, and practically forming a cylinder, and that the free wheels will have special advantages in passing round curves, because the wheel on the outer rail can rotate to accord with the longer length. This theory is fallacious, for the axles are held parallel, and cannot form radii of the curve; therefore the wheels, when passing curves, must necessarily be forced round by a sliding process. If, for illustration, the front axle of an ordinary road carriage be lashed so that it cannot swing round, and the attempt be then made to drive round a street-corner, it will be seen that the looseness of the wheels will not make the operation less impracticable. The loose wheels are therefore useless, and experience shows them to be absolutely detrimental.

An ingenious wheel is used in America, having a second rim or tread on the inside, of a lesser diameter than the other. On coming to facing points this second tread strikes on an inclined plane, the car runs up out of the ordinary groove, and is led over on this elevation into its proper line, when it falls to the same level. By fitting the cars with or without this additional tread, movable points and pointsmen may be entirely dispensed with. The system works well in America, but the elevation in the points would be objectionable in this country.

Brakes.—At first brakes were applied to the treads of car wheels, as on railways; but it was soon seen that the circumstances were different. On railways a deep flange is necessary, and this is not in any way injurious to the rail. On tramways a very slight flange is adequate, and a deep flange would be positively injurious, as it increases the resistance and splits the rail. The tread of the wheel has evidently a tendency to wear more rapidly than the flange, and it is, therefore, necessary to wear down the flange proportionately, so as to keep it off the bottom of the groove. This work is best done by chilled iron brakes. The system of using wood for tramway brakes, with the view of saving the wheels, is therefore fallacious, the wheels being saved at the expense of rails and horses.

Timber.—The peculiar construction of cars with short wheel base and great overhang, coupled with the immense loads they constantly have to carry, renders it necessary that unusual care be taken in their construction, and in nothing more than in the seasoning of the timber. Oak is the best timber to choose for the substructure, and ash for the superstructure.

Endurance.—Cars worked constantly on roads having heavy gradients should last about ten years. It is doubtful if any car in this country will last, even with much renewing, over fifteen years. Some of Messrs. Stephenson's cars have been known to last nearly twenty years in America; in fact, some of that age are certified to be still at work in New York, on "Commodore Vanderbilt's Road."

Size.—The size of the cars may be to some extent ruled by the expected traffic and gradients; but two-horse cars accommodating forty-two passengers are generally useful. Some thought has been expended in arriving at a medium weight, which, while it permits of the car being constructed in a sufficiently substantial manner, is yet not so great as to unreasonably distress the horses. Where steam is used as the motive power, it will probably be

prudent to increase the weight and substantiality of the cars. One-horse cars are used freely in America, and to a limited extent in this country. They may be of use where the road is level and the traffic light. The gearing, wheels, &c., of the cars, whether two-horse or one-horse, must be to a great extent similar; so that, in the latter case, the horse has more dead weight to pull.

The communication is accompanied by a series of diagrams, from which Plate 1 has been compiled.

TRAMWAY

Name of Company.	Miles of Line open.	Capital received.			
		Ordinary Shares.	Preference Shares.	Debentures and Loans.	Total.
		£.	£.	£.	£.
NORTH METROPOLITAN.					
Half-year ending June 30, 1875 .	29½	600,000	..	69,700	669,700
,, ,, Dec. 31, 1875 .	30½	600,000	..	80,200	680,200
,, ,, June 30, 1876 .	30½	600,000	..	85,000	685,000
,, ,, Dec. 31, 1876 .	30½	600,000	..	85,000	685,000
LONDON TRAMWAYS.					
Half-year ending June 30, 1875 .	20¼	250,000	80,000	94,700	424,700
,, ,, Dec. 31, 1875 .	20¼	250,000	80,000	99,750	429,750
,, ,, June 30, 1876 .	20¼	250,000	80,000	101,050	431,050
,, ,, Dec. 31, 1876 .	20¼	250,000	80,000	101,050	431,050
LONDON STREET TRAMWAYS.					
Half-year ending June 30, 1875 .	4½	90,490	..	37,300	127,790
,, ,, Dec. 31, 1875 .	5½	94,900	..	42,000	136,900
Year ,, Dec. 31, 1876 .	5½	100,000	..	40,750	140,750
GLASGOW TRAMWAYS.[1]					
Half-year ending June 30, 1875 .	15	287,644	..	..	287,644
,, ,, Dec. 31, 1875 .	15	287,644	..	..	287,644
,, ,, June 30, 1876 .	15	287,654	..	..	287,654
,, ,, Dec. 31, 1876 .	15	287,654	..	..	287,654
EDINBURGH TRAMWAYS.					
Half-year ending June 30, 1875 .	13	149,060	..	40,450	189,510
,, ,, Dec. 31, 1875 .	13	149,540	..	45,500	195,040
,, ,, June 30, 1876 .	13	149,550	..	40,262	189,812
,, ,, Dec. 31, 1876 .	13	149,720	..	40,130	189,850
DUBLIN TRAMWAYS.					
Half-year ending June 30, 1875 .	15	239,956	..	15,000	254,956
,, ,, Dec. 31, 1875 .	15	240,000	..	15,000	255,000
,, ,, June 30, 1876 .	15	240,000	..	15,000	255,000
,, ,, Dec. 31, 1876 .	15	240,000	..	15,000	255,000
CARDIFF TRAMWAYS.					
Half-year ending June 30, 1875 .	2½	35,000	..	..	35,000
,, ,, Dec. 31, 1875 .	2½	35,000	..	..	35,000
PORTSMOUTH TRAMWAYS.					
Half-year ending June 30, 1875 .	3	42,514	..	..	42,514
,, ,, Dec. 31, 1875 .	3	42,625	..	..	42,625
PLYMOUTH TRAMWAYS.					
Half-year ending June 30, 1875 .	1¾	33,883	..	..	33,883
,, ,, Dec. 31, 1875 .	1¾	35,921	..	..	35,921

[1] Under special arrangements.

STATISTICS. (For continuation see next page.)

Capital expended.			Number of Horses.	Number of Cars and Omnibuses.	Traffic.				
Construction, Equipment, and Buildings.	Horses.	Total.			Passengers carried.	Miles run.	Traffic Receipts.	Receipts per Mile of Tram.	Receipts per Mile run.
£.	£.	£.					£.	£.	£.
682,662	Horsed by L. G. O. Co.	682,662	..	164	13,488,354	1,714,917	112,372	3,809	15·73
684,566		684,566	..	168	14,267,563	1,841,767	121,894	3,996	15·89
684,632		684,632	..	166	13,065,184	1,768,559	113,231	3,712	15·37
684,632		684,632	..	166	13,789,270	1,800,441	119,468	3,917	15·92
362,116	50,208	412,324	1,209	139	7,583,400	1,224,272	67,661	3,399	13·50
368,957	49,708	418,665	1,197	145	8,207,567	1,273,371	70,389	3,543	13·51
372,575	44,093	416,668	1,060	147	7,881,537	1,192,542	67,454	3,331	13·57
375,033	44,093	419,126	1,060	147	7,713,999	1,137,161	68,033	3,359	14·35
132,925	16,308	149,233	400	48	2,575,320	330,174	20,714	4,602	15·05
134,826	16,308	151,134	400	48	2,778,761	367,167	23,233	4,224	15·10
137,028	16,538	153,566	400	48	5,620,880	772,598	46,829	8,514	14·55
235,599	25,950	261,549	865	139	..	845,306	54,744	3,649	15·54
239,324	32,375	271,699	925	149	..	913,536	63,010	4,200	16·55
272,410	43,563	315,973	1,180	182	..	1,074,528	67,579	4,505	15·09
288,981	51,177	340,158	1,368	197	..	1,235,832	75,006	5,000	14·56
Special circumstances.							Including omnibus receipts.		
195,053	12,979	208,032	407	43	..	352,738	26,030	2,002	17·71
198,317	16,017	214,334	478	41	..	415,031	29,603	2,277	17·11
200,761	17,834	218,595	482	48	..	..	28,904	2,223	..
203,853	16,909	220,762	457	48	..	..	31,622	2,433	..
Special circumstances.									
235,827	17,258	253,085	486	79	2,734,807	495,137	33,152	2,210	16·06
235,827	16,088	251,915	456	85	3,049,925	543,587	36,738	2,449	16·22
235,827	17,971	253,798	500	79	2,904,592	..	35,120	2,341	..
235,827	17,364	253,191	486	81	3,169,045	..	38,129	2,542	..
32,747	1,680	34,427	56	12	490,627	59,992	4,088	1,635	16·35
32,847	1,680	34,527	55	12	632,159	66,874	5,667	2,106	18·90
40,624	1,890	42,514	63	12	489,282	76,045	3,440	1,146	10·86
40,735	1,890	42,625	63	12	432,448	82,160	3,994	1,331	11·54
31,483	2,400	33,883	76	12	836,863	63,002	4,748	2,713	17·13
33,521	2,400	35,921	82	12	734,489	68,427	5,469	3,125	19·18

TRAMWAY STATISTICS—*continued.*

Name of Company.	Working Expenses.					Percentage of Working Expenses to Gross Receipts.	Dividends. Ordinary Shares.	
	Working and General Expenses including Track Repairs.	Per Mile of Tram.	Per Mile run.	Track Repairs.	Per Mile of Tram.		Per cent.	Total.
	£.	£.	d.	£.	£.			
NORTH METROPOLITAN.								
Half-year ending June 30, 1875	84,748	2,872	11·85	2,362	80	73¾	8	24,000
,, ,, Dec. 31, 1875	91,194	2,990	11·91	2,387	78	73½	8½	25,500
,, ,, June 30, 1876	88,604	2,905	12·02	2,467	81	76½	8	24,000
,, ,, Dec. 31, 1876	89,269	2,927	11·89	4,271	140	73	9	27,000
LONDON TRAMWAYS.								
Half-year ending June 30, 1875	60,702	2,975	11·81	1,063	52	..	nil	..
,, ,, Dec. 31, 1875	63,109	3,116	11·89	1,549	75	87¾	..	..
,, ,, June 30, 1876	66,192	3,268	13·32	2,919	144	96½	..	..
,, ,, Dec. 31, 1876	51,597	2,548	10·88	1,694	84	75¾	3	3,750
LONDON STREET TRAMWAYS.								
Half-year ending June 30, 1875	16,171	3,593	11·75	550	122	..	7½	2,892
,, ,, Dec. 31, 1875	18,689	3,308	12·21	518	94	..	7	3,321
Year ,, Dec. 31, 1876	37,081	6,742	11·51	1,246	226	80¼	6	5,936
GLASGOW TRAMWAYS.[1]								
Half-year ending June 30, 1875	44,469	2,964	12·62	..	..	..	nil	..
,, ,, Dec. 31, 1875	49,422	3,294	12·98	..	..	76½	3	4,375
,, ,, June 30, 1876	52,164	3,477	11·65	..	..	75	3	4,375
,, ,, Dec. 31, 1876	56,530	3,768	10·97	..	..	74	4	5,833
EDINBURGH TRAMWAYS.								
Half-year ending June 30, 1875	19,522	1,501	13·28	664	51	..	6	4,500
,, ,, Dec. 31, 1875	22,499	1,730	13·01	1,031	79	..	6	4,500
,, ,, June 30, 1876	24,601	1,893	..	708	54	82½	4	3,000
,, ,, Dec. 31, 1876	22,498	1,730	..	1,689	130	70	8	6,000
DUBLIN TRAMWAYS.								
Half-year ending June 30, 1875	24,741	1,649	11·99	1,137	76	73½	6	7,200
,, ,, Dec. 31, 1875	25,079	1,672	11·07	1,404	93	67	8	9,600
,, ,, June 30, 1876	23,919	1,593	..	1,740	116	67	8	9,600
,, ,, Dec. 31, 1876	25,492	1,699	..	2,243	149	66	9	10,800
CARDIFF TRAMWAYS.								
Half-year ending June 30, 1875	3,320	1,328	13·28	67	26·8	about 68	10	750
,, ,, Dec. 31, 1875	3,360	1,344	12·05	113	45·2			1,750
PORTSMOUTH TRAMWAYS.								
Half-year ending June 30, 1875	3,077	1,025	9·57	57	19	about 83	3	350
,, ,, Dec. 31, 1875	3,122	1,040	9·11	17	5·6			650
PLYMOUTH TRAMWAYS.								
Half-year ending June 30, 1875	4,330	2,474	16·49	57	32·57	about 85	4½	400
,, ,, Dec. 31, 1875	4,567	2,617	16·01	53	30·30			800

[1] Under special arrangements.

Mr. HUNTINGTON said the question of tramways had taken such a footing in English construction that it was quite time to have a fair and deliberate discussion concerning it. Tramways would in future form an important part in conveyance, especially in situations where the cost or the site of a railway might be inexpedient, and that not only in England, but also in the Colonies and in other places where English skill might be called for. He regretted that the Author had given so little information as to the cost of the different systems in relation to the actual construction. The statement that the cost varied from £1,500 to £6,000 a mile was very vague. He had been interested, as a shareholder, in undertakings of that kind, and had found the information given at public meetings to be of an unsatisfactory character. In London certain tramways might be said to be in full working condition, such as the North Metropolitan and the London or South system; in Dublin also they had been at work for a long period. Some were worked by horse contract, like the North Metropolitan, and others horsed themselves, like the London and the Dublin. The capitals of the companies varied considerably, as also did the results of working the roads. In making a comparison, in addition to the tramways, he had thought that it would be instructive to join thereto the railway system and the omnibus system, for which purpose he had selected the Metropolitan, the Metropolitan District, and the North London railways, as a group approaching the nearest to the tramways for conveying passengers. The length of the North Metropolitan tramway was 30½ miles; the London, 20¼ miles; the Dublin, 15 miles; the length of the group of railways was 32 miles; and the General Omnibus Company covered a range of 58½ miles. The cost for six months to the 31st of December, 1876, of the North Metropolitan had been £22,447 per mile; of the London, £20,697; of the Dublin, £17,125; of the group of railways, £578,320; and the capital of the General Omnibus Company was equal to £10,264 per mile. To put the North Metropolitan on a fair level with the others, the cost of horse stock and equipments (on the London scale) should be added, or £3,040 per mile, making that system cost £25,487 per mile, or about £6,000 per mile dearer than the London. The item "Tramways," which included the roads, paving, engineering, extra works, preliminary

and parliamentary expenses, cost on the London £15,005 per mile, which might be analysed thus:—

	£.
Double line of tramways	3,000
Paving, 6 yards wide	8,000
Engineering	1,000
Extra works, &c.	2,000
Parliamentary, &c.	1,000
	15,000

Besides these expenses the London cost £2,177 per mile for horse stock, also £1,959 per mile for cars and other plant, and £1,555 per mile for land and buildings; while the cost of the North Metropolitan for the last two items only was £1,077 and £1,345 per mile respectively. Taking the single passenger as the unit, the North Metropolitan carried 2,457 per mile per day; the London, 2,070; the Dublin, 1,150; the railway group, 7,735; and the General Omnibus Company, 2,450. The receipts per passenger were: North Metropolitan, 2·08*d.*; the London, 2·10*d.*; the Dublin, 2·88*d.*; the railways, 2·57*d.*; the General Omnibus Company, 2·53*d.* The horsing of the North Metropolitan was done by the General Omnibus Company, and the contract amounted to 0·88*d.* per passenger; the London horsed itself, and the cost, including renewal of horses, was 0·81*d.* per passenger, and the Dublin cost for horsing and renewal, 0·88*d.* The locomotive cost on the railways was only 0·35*d.* per passenger. The cost per passenger for the horsing of the General Omnibus Company was 1·31*d.* With regard to the railways, the returns contained the gross receipts for goods and the total gross receipts, so that the gross passenger receipts could be ascertained; but, as far as expenditure was concerned, the returns combined both, and a separation therefore had to be made by computation and approximation. The total cost under each system respectively was: North Metropolitan, 1·51*d.*; the London, 1·57*d.*; the Dublin, 1·88*d.*; the railways, 0·88*d.*; and the General Omnibus Company, 2·11*d.* per passenger. The general results showed that the railway system had at all events the advantage of economy. The probable cost of steam on tramways had been stated by the Author as 25*s.* 1*d.* per car per day, which nearly agreed with his own calculation. He had not taken into account, what the Author had included, the renewal of engine, &c.; in the Tramway reports he found it

as renewal of horses, plant, and other matters, and left it to stand as the equivalent of the new form of renewal.

	s.	d.
Fuel, 7 cwt. (during eighteen hours)	7	11
Engineman and stoker at 6s. per day above the present wages of driver	6	0
Sundries, oil, waste, tools, materials, assistance, &c.	1	10
Interest on capital for reforming road and stock	2	10
Contingencies	1	5
Renewals, now charged for horses $\frac{1}{8}$d. per passenger	5	2
Total per car per day	25	2

Therefore, withdrawing the renewals from this estimate as being elsewhere included, and taking the steam alone, he calculated the amount to be as nearly as possible £1 per car per day. Thus the cost on the North Metropolitan, running one hundred and forty cars per day, would be £140; and applying that to 14,000,000 passengers in the half-year, the amount was 0·44*d.* per passenger; also in the case of the London it was 0·45*d.* That gave a *bonâ fide* gain of about 0·4*d.* in favour of mechanical motive power, which was equal to an increased dividend of 8 per cent. or more. By comparing the tramways with the railways in the subjoined table it would be seen that, although the system by steam had great advantages in large cities, where passengers were numerous and distances short, the cost of steam was considerably augmented in country districts, where there were fewer passengers and longer distances to travel. During the six or seven years that tramways had been working, roads, cars, plant, and horses had been more or less subject to renewals. The roads cost about £4,000 per mile, double line, including engineering and other matters exclusive of the paving. Up to the present time the total renewal from the 1st of January, 1871, of the tramway upon the North Metropolitan had amounted to £601 (or £777 including the contractor's outlay) out of £4,000, and on the London to £936. If renewals went on at that rate obviously a considerable period would elapse before the tramway was thoroughly worn out; but there was a slow annual increase in this item, which in 1871 was about £88, and in 1876 became £220 per mile on both tramways. With regard, however, to the cars and other plant, the original outlay was £1,133 per mile on the North Metropolitan, and the company had already spent in renewal £1,311. On the London the original cost was £1,919 per mile, and up to the present the repairs had amounted to £1,442, so that the American statement of a ten-years' life did not appear to be borne out. For horses the original cost per mile on the

London amounted to £2,480, and the renewal to £1,540. The actual reserves in hand to meet the renewals exclusive of these annual outlays were for the North Metropolitan £738, and for the London £595 per mile; sums insufficient, seeing that the annual outlays were already £250 per mile for roads, cars, &c., and £142 per mile for horses. With regard to the tramway itself, he had received the following particulars three or four years ago from a gentleman connected with the construction of the line. The price of iron, timber, and labour was constantly varying at the time, so that the figures could not be taken as an accurate estimate of what the real cost had been:—

	Per yard. s.	d.
Rails, ties, spikes, bolts, dogs, fishes, &c. (rails 50 lbs. per yard at £10 10s. delivered)	10	6
Timber creosoted and shaped	2	0
Fixing and laying, including crossings	1	0
Maintenance for one year	0	6
Contingencies, cartage, lights, watching, waste, and cutting	1	6
Risk and profits 10 per cent.	1	6
Total	17	0

1,760 yards at 17*s.* = £1,496, say £1,500 per mile of single line.

Paving with 7-inch cubes of granite for a double road with concrete bottom cost:—

	Per square yard. s.	d.
Granite paving set to tramways, 18 feet wide, materials and labour	11	0
Concrete, averaging 6 inches thick, including excavation and removal of road	1	6
Contingencies, grouting, carting, watching, removing materials, and sanding	1	0
Maintenance for one year	0	3
Risk and profit 10 per cent.	1	3
Total	15	0

1,760 × 6 × 15*s.* = £7,920, say £8,000 per mile of double line.

He had also obtained the following particulars:—Gauge, 4 feet 8½ inches with a 4-feet midway. Rails, dogged on kyanised longitudinal bearers 21 feet long, with four transverse bearers bolted with ¾-inch bolts and nuts to the gauge, the weight being, as computed after measurement, 45 lbs. per yard. The gauge was kept by the paving. The dogs were 4 inches long, ⅝ inch in diameter, and were driven into drilled holes on both sides of the rails, slightly angular, about 3 feet apart, one side dividing the space with the other. The dogs were driven into the timber after being well screwed down by a double-sided square-threaded cramp. The joints were fished with plates 9 inches long, ⅜ inch thick, let

into the longitudinals. The timbers were bedded in Portland cement concrete 6 inches thick, and the paving was laid upon the same. The sifted rubble of the road was used for grouting, and fine red sand was laid above all. The paving extended 1 foot 6 inches on each side of the outer rails, 7-inch granite cubes being used. Extra works, crossings, and sidings, were not included in the above estimates. The following table illustrated the foregoing remarks more correctly :—

DETAILS of the COMPARATIVE COST of CONVEYING ONE PASSENGER by TRAMWAY, OMNIBUS, and RAILWAY; the TWO FORMER SYSTEMS for ONE YEAR ENDING the 31st of DECEMBER, 1876, and the RAILWAY SYSTEM for ONE YEAR ENDING the 31st of DECEMBER, 1875.

Item.	Tramways.			Omnibus.	Railways.[1]	
	North Metropolitan.	London (South).	Dublin.	London, General.	North London, Metropolitan, and District.	Nine great trunk lines from London.
	d.	*d.*	*d.*	*d.*	*d.*	*d.*
Horsing (net)	0·897	0·808	0·761	1·139	..	..
Renewal of horses	..	0·156	0·099	0·215	..	..
Locomotive, passengers only	..	..	..	..	0·348	1·745
Wages	0·358	0·349	0·482	0·490		
Miscellaneous	0·066	0·091	0·083	0·019		
Repairs of cars	0·067	0·090	0·101	0·136	0·076	0·476
„ road	0·060	0·072	0·157	..	0·123	1·286
„ plant	..	0·016	0·027	0·062		
Rents, rates (net)	0·047	0·127	0·095	0·058	0·076	0·275
Duties	0·006	0·009	..	0·006	0·094	0·500
Compensations	0·007	0·025	0·026	0·012	0·015	0·228
Law and parliamenty.	0·023	0·026	0·034	0·031	0·151	0·804
General (net)	0·010	0·013	0·041			
Total cost	1·541	1·782	1·906	2·168	0·883	5·314
„ receipts	2·078	2·076	2·895	2·552	2·576	13·031
Gross profit	0·537	0·294	0·989	0·384	1·693	7·717
Capital expended per passenger, adding horses	6·856	6·420	10·382	2·800	31·160	99·520
Passengers per mile per day	2,405	2,104	1,106	2,400	7,735	117
	£.	*£.*	*£.*	*£.*	*£.*	*£.*
Cost per mile	25,487	20,697	17,125	10,264	578,320	58,245
Miles open, all as in double line	30½	20¼	15	58½	32	5,875

[1] The cost of goods is eliminated from the railways.

Mr. HEAD had not studied the subject very much, but he had had a great deal to do with traction engines on roads. In considering the application of steam to tramways, it should be remembered that the gradients could not be altered, so that the engine had to work upon a variety of gradients according to circumstances. Two kinds of engines—separate and combined—had to be constructed for tramway cars. There were many advantages in the separate engines constructed by Mr. Merryweather and Mr. Hughes. The companies using those engines could employ their present rolling stock; the passengers had not the same fear of being blown up if the boiler should burst as when the engine and car were combined; and the public had an idea that the system was the right one from association with railway trains. At the same time, looking at the gradients of the lines in London, Edinburgh, Liverpool, and other places, he thought there would be a good deal of difficulty in getting an engine weighing from 4 to 5 tons up some of the inclines in wet, foggy weather. It was difficult, however, to bring data forward of what could be done under such circumstances. The experience with traction engines on roads showed that in damp weather adhesion was small. Horses could always haul the cars, for, if two would not suffice, a third, and even a fourth, could be added; but if an engine could not get on in wet weather the whole traffic might be blocked. With an engine on the principle of Mr. Grantham's there was the whole of the adhesion from the combined weights of the engine and boiler, the car, and the passengers. It was unnecessary to say that adhesion was practically the keystone to the propelling power of the car, and that an engine of great weight had more power to propel itself than one of light weight. These important matters must be cleared up before tramway companies could decide upon the best engine to be employed. There might be one or two level lines on which a separate engine could be used with advantage, but he thought there were many lines in London which could only be worked safely with a combined engine and car.

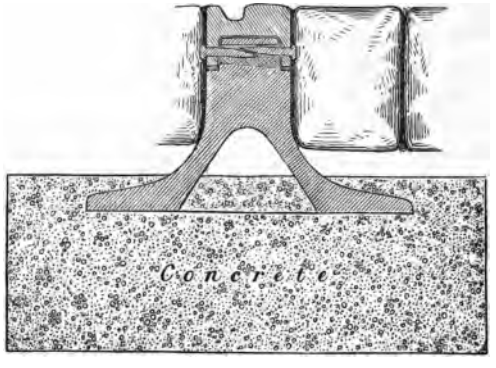
Mr. LONGRIDGE said it was evident that separate engines could only be employed where there were easy gradients. He had seen an engine of Mr. Merryweather's at Vienna, and it struck him at the time that there would be considerable difficulty with a steep gradient. It weighed 3½ or 4 tons, and, including car and passengers, the total weight would be about 10 tons. With a gradient of 1 in 20 that weight would require a tractive force of about 1,482 lbs. He took the friction of the engine at 20 lbs., and of the car at 15 lbs. The insistent weight was the weight of

the engine itself, 4 tons, and he believed that in ordinarily slippery weather the adhesion would be not more than one-tenth, or 896 lbs. Under those circumstances he did not think it possible to work with any satisfaction. Much the same thing applied to Mr. Grantham's car, which he also saw at Vienna. It went very well on level ground, or on a moderate inclination, and there was no nuisance from blast, sparks, or smoke; but in that case the engine was placed at one end of the car, and the driving wheels beside the engine. About two-thirds of the way towards the other end there was a bogie with four wheels, and the only adhesion that could be obtained was the adhesion upon the driving wheels of the engine, which would not amount to more than one-half of the total weight. The same difficulty therefore arose as in the case of Mr. Merryweather's car, and he knew that considerable trouble had been experienced at Vienna with a gradient of 1 in 24 when the rails were at all out of order. It was not only the slipperiness of the rails that affected the tramway, but their inequalities. The constant passage of heavy traffic made it impossible to keep the rails in the same order as on a railway, so that one wheel would perhaps bear scarcely at all on the rail, and the other would bear very heavily. For steam traction it would be necessary to devise some means of utilising the whole of the carrying wheels of the car, and that he thought might be readily accomplished with Mr. Grantham's car. Another difficulty in the way was the great variation in the work to be done at different times. In the case of Mr. Merryweather's car, running nearly empty on a level, at 8 miles an hour, a tractive force was required of 2½ HP., whereas on a gradient of 1 in 20, a tractive force of 19 HP. was needed. With the small boiler necessarily used in such cases, he considered it would be difficult to regulate the fire and the generation of steam so as to meet those varying conditions. The steam would sometimes blow off with violence, which would be objectionable, and would perhaps be experienced with almost all steam engines. No doubt many objections would be avoided by the use of compressed air, but that was an extravagant mode of getting power. Compressed air was not itself a motive power, but only a method of applying it, the power being in the steam engine which compressed the air. M. Mékarski found that for every horse-power, effective, obtained in compressed air, an amount of 5 steam HP. was needed, so that the power actually used was only 20 per cent. There appeared to be an error in the Author's comparison of the pneumatic car with steam power. He estimated, for instance, the fuel by steam power at 5*s.* per day, and in the pneumatic car at 2*s.* 6*d.*,

whereas if M. Mékarski was right, it should be five times as much. A combination of compressed air and steam had been brought under his notice, the power being obtained by the explosion of ordinary coal gas. It seemed ingenious and likely to prove of value. It avoided all the difficulties arising from noise, smoke, and the like, and was always perfectly at command, since it could be varied almost at any moment from 2 HP. to 20 HP. Although gas, as fuel, was expensive, he thought the expense would be far more than counterbalanced by the great advantages that would be obtained.

Mr. A. M. FOWLER said, in Salford 22 miles of tramway were being laid down, and great anxiety had been felt as to the best mode of construction. He was surprised to find that the Author had come to the conclusion that a timber foundation was the best for large towns. With regard to side fastenings, he agreed with the Author, that unless the paving stones were brought close to the iron the necessities of the case in regard to heavy traffic in large towns could not be met. In Salford a system had been adopted (Fig. 1) to

FIG. 1.



which the objections raised in the Paper were not applicable. There was a deep flange under the rail, a close joint to the iron, and by having a fastening every 3 feet it was impossible that the traffic could produce any detrimental effect upon the surface of the street. The paving setts were bedded in ashes on the top of the concrete. The first portion of the line had been laid about two months, and although the traffic had been heavy there was no crack or break in the joints of the paving. Before the Salford committee decided upon that plan, they had visited almost every town in England where the best-known systems of construction were em-

ployed, and, after his report, they came to the unanimous conclusion to adopt that system. The Author had stated that, by having the timber foundation set back from the face of the rail, the fastening was made flush with the side of the rail. That allowed for the width of the dog, or the fastening, and it allowed for the sett to come close to the rails. In tramway construction the object was to preserve the foundation, and if it was preserved by keeping out the water, vibration was to a great extent prevented. He did not suppose that the setts were grouted, as in London, with lias lime, or, as in Lancashire and Yorkshire, with asphalt concrete; the space would require to be filled up, otherwise the water would get in, and so it would work loose. He thought the asphalt or concrete would not adhere so well to timber as it would to iron, and that a continuous bearing was objectionable. If the vibration of the rail was to be reduced to a minimum, the bearings should be about 2 or 3 feet apart. In the old plan of railway construction, with longitudinal timbers, the vibration in the foundation had been so great, that transverse sleepers had been resorted to. If such sleepers were laid solid throughout, the structure would not be so good. With a rigid longitudinal foundation, packed hard in the centre, it must necessarily tilt, just as a flag in a street would when not bedded well at the corners. He did not wish to say anything against a continuous iron bearing, or a foundation of iron under a portion of the setts; but he maintained that if there was not a uniform foundation for the setts they would tilt. He had found that to be so in tramways already constructed on that principle. Railways were generally level, as compared with tramways, the latter having to be regulated according to the inclination of the streets; and he did not think it would be safe to construct tramways of steel where the gradients were as steep as 1 in 20. On that ground he had adopted the old iron rail. He did not agree with the Author that the fastenings of timber should be more numerous. If the fastenings by dogs were numerous, there would be a tendency to split the timber, and the wear would not be so permanent.

Mr. Livesey described a road that had been largely used in South America, composed entirely of iron and steel. Seven years ago he designed for Buenos Ayres a tramway in which the rail was of steel, and the channel dovetailed, so that the fastening would not project and interfere with the stones. More than 100 miles had been sent to South America, and laid down in the interval. In Buenos Ayres the timber roads were being taken up and relaid with iron roads, which were much more durable, and in the end more

economical. He greatly preferred steel rails to iron rails whenever the capital could be afforded, as the former did not wear so soon; indeed some of the iron rails had already been renewed. He believed that an iron permanent way would ultimately supersede the use of timber, and that an iron road with a steel rail would last thirty or forty years, if not longer.

Mr. J. H. LYNDE remarked that the traffic on tramways was different from that upon railways, and that the pavement abutting upon the rail was subjected to much extra wear and tear by the ordinary traffic. Thus it was important that this part of the pavement should be provided with such a foundation as would prevent the subsidence of the setts, which had proved to be the great objection to the introduction of tramways. As the pavement was practically rigid, so the materials used in constructing a tramway should be rigid; moreover the materials should not be liable to decay. The tramway adopted in Manchester fulfilled these conditions. The foundation was a continuous series of cast-iron bearers provided with side flanges for the support of the adjacent setts, and a deep groove on the upper surface for the reception of the tongue of the steel rail, which was keyed down by means of wedge cotters passing through the cast-iron bearer and the tongue of the rail. No difficulty had been experienced in laying the tramway, and as much as 220 lineal yards complete had been executed in one day by a gang of sixteen men. The cost of this system, which was known as "Barker's Patent," varied from about £2,000 to £2,300 per mile, according to the weight of metal and depth of pavement used. The Manchester line consisted of 212 tons of cast-iron bearers and 63 tons of steel rails to the mile of single line. One great advantage of this tramway was, that the rails could be renewed with but little interference with the cast-iron bearers or the pavement, and, also, that the delay and difficulty of using concrete were avoided, except in rare instances of soft foundation.

Mr. LAWFORD agreed with the views of the Author, with one or two exceptions. He had stated that asphalt and wood paving had always proved failures. On the south side of London there was a tramway the first 400 yards of which were paved with asphalt. There were stone setts on each side of the rails, and also at 18 inches outside the rail where it joined the macadam; and it was as good a piece of tramway as could be seen. The mischief arose where the asphalt joined the macadam, and there there was a series of ruts. The same remark applied to wooden pavement. About 200 yards of similar tramway, near

Clapham Rise, were paved entirely with wood, for the purpose of deadening the sound in front of the Home for Incurables. Whatever the pavement was, it should, he thought, be carried across the road; and in that case as good a job might be made with wood or asphalt as with stone. The only other matter on which he disagreed with the Author was with regard to cost. He should like to see a street tramway made for £1,500 a mile. He had made the Duke of Buckingham's tramway, which was not, strictly speaking, a street tramway, but it crossed wide public and turnpike roads. It was 8 miles in length, and had been in existence nearly seven years. The rails, weighing 30 lbs. to the yard, were laid on longitudinal sleepers, and the gauge was 4 feet 8½ inches. For the first twelve months it was worked entirely with horses, and since then it had been worked by steam, which had proved more economical. Two of Aveling and Porter's traction engines had been built for the purpose, fitted with flanged wheels, and they had acted extremely well. The speed was from 4 to 8 miles an hour, the average being about 6 miles. Within the last six months a small four-wheeled coupled locomotive, rather lighter than a traction engine, had been introduced. The manager of the line had informed him that the cost of haulage by horses was £1 12*s.* 11*d.*, as against £1 by steam; adding, "in my desire to be impartial, I think I have rather underestimated the cost of horse haulage." The maintenance of the line, exclusive of renewals, was £63 7*s.* 6*d.* per mile per annum. The steepest gradient was 1 in 45 for about ¼ mile; the others were easy, practicable gradients. It was a single line with sidings, and was made at a cost slightly under £1,400 per mile, when rails were rising considerably in price. No mention had been made of the internal dimensions of the cars. On the south side of London the directors tried to pack eleven people inside. He thought there should be a division into two classes, as on the continental tramways. A premium had been offered by the General Omnibus Company for the best method of checking the fares. He did not know whether a mechanical mode of checking the takings of the conductors was possible; but a move had been made in that direction on the south side of London; one uniform fare was charged for any distance, and as each ticket was punched, a little piece of paper fell into a box (not under the conductor's control) with the operation.

Mr. C. H. Beloe thought the subject of street tramways had not received the attention which it deserved from the profession. Their construction had been in the hands of comparatively few engineers in England, but the time was coming when works of

that kind would be greatly extended. The hurried manner in which street tramways were generally constructed was a matter deserving serious consideration; and it was a wonder the roads stood as well as they did. An effort should be made to obtain from the Board of Trade some relaxation of the rule limiting the amount of roadway to be opened at one time to 100 yards. Local authorities were very severe in enforcing those restrictions upon tramway companies. Companies were often blind to their own interest in urging engineers to push forward their works so rapidly. To assist in rapid work the Author recommended the use of bituminous concrete. He had tried it, but it had not answered his expectations. The Glasgow tramways were laid almost exclusively upon bituminous concrete, and the paving had sunk there to a greater extent than he had observed anywhere else—certainly more than it did upon cement concrete, if time were given for it to set. If any material could be found which would set more quickly than cement concrete, a great advance would be made in the construction of tramways. He agreed with the Author in his approval of cross sleepers. He had recently laid a road with tie-rods. It was a macadamised road with hard rock pitching underneath; cross sleepers would have involved excavating the hard rock pitching, and then the foundation of the road would have been seriously weakened. Under those circumstances he was induced to use tie-rods; but though the expense was considerably reduced, he regretted that he had not taken out the old pitching, and laid a substantial bed of concrete. The box rail was certainly a good one; but having regard to the probability of increased weight on tramways in the future, and to the introduction of steam locomotives, he was inclined to think that the ⊤-shaped rail was the best. He did not object to the use of the rail with the central groove, because he thought it the best form for tramway purposes. The waste of the guard rail, carrying no traffic, was saved, and the whole surface of the rail for the tread of the wheel was utilised. Nor did he think that the flange was weakened, or that the car was more liable to leave the rail. In his opinion a simple form of construction would be two ordinary flat bars set on edge, and secured to cast-iron chairs, resting on cross sleepers. If necessary the chairs could be cast to receive wooden cushions under the rail to deaden vibration; but he believed that by the use of the central groove the width of the rail could be diminished and many other advantages be obtained. He should watch the use of it in Liverpool with great interest. He agreed in the recommendation of tar grouting, which was extensively used

in the North of England. The principal objection to it was the impossibility of applying it in wet weather. Borough engineers could stop up a whole street and cover it with a roof under which to carry on grouting operations; but the ordinary tramway engineer was not so fortunate; and hence tar grouting, though most effectual, was useless unless a continuance of fine weather could be insured; because the grouting must proceed as rapidly as the rest of the work, and a few days' rain would spoil the whole operation. He did not agree in the disapproval of cast-iron crossings and preference for cut rails. Cast-iron crossings were not as durable as could be desired, but no doubt in a short time steel points and crossings would be cast, though hitherto he had failed to obtain them. It was difficult to make a neat crossing by cutting iron rails, but it was much more difficult to do so with steel rails. He believed that iron tramways would supersede wooden ones. He had watched the process of laying the tramway in Manchester, and noticed that the workmen had no difficulty in pinning down the rail to the cast-iron sleeper. With regard to the cost of tramways, he thought that a single line, including paving, but without any contingent expenses for engineering or company's affairs, might be set down at from £4,000 to £4,500 a mile. It was difficult to estimate the cost of repairs, although it seemed that there had been a great increase in the cost of renewals and of repairs of late years. He hoped that the new tramways now being laid would show a better result in that respect than their predecessors.

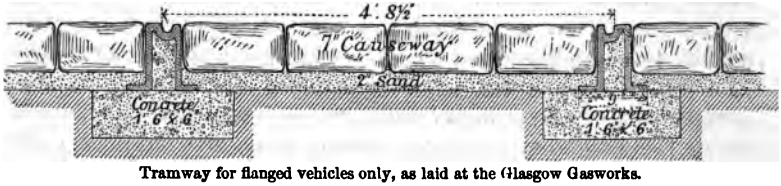
Mr. RAPIER said, several years ago Mr. Deas, M. Inst. C.E., consulted him as to the best way of obtaining some easement to the traffic along the Broomielaw, Glasgow. At the time he referred Mr. Deas to the tramways for ordinary street traffic at Ipswich, and in the Devonshire Street goods yard, which had been worked for twenty years without repairs, not subject, however, to such incessant traffic as that of Glasgow. The result was the construction of the tramways on the principle shown by Figs. 2 and 3, in which

FIG. 2.

Cast-iron Tramway for dock purposes for flanged vehicles, or ordinary street lorries, as laid on the Glasgow Quay.

it would be seen that the bottom flange was discarded. These tramways had been in constant work for seven years, and had not cost sixpence a mile for maintenance or renewal, or repair of any

FIG. 3.



Tramway for flanged vehicles only, as laid at the Glasgow Gasworks.

kind. At first it seemed desirable to have a bottom flange at the outside of the blocks, but it was found inconvenient in fixing the paving setts. The bottom flange was then put on the inside; that did very well, but, economy being the order of the day, it was cut away altogether with the most satisfactory results. The blocks, which were adapted both for flanged and unflanged vehicles, were cast with recesses at the ends to receive fish-plates, which were bolted in the ordinary manner. The blocks were entirely filled with concrete composed of 1 part of Portland cement and 7 parts of gravel and sand well punned in, and allowed to lie three or four days to set. The road was made like an ordinary first-class street or dock road, with the bottom in dry rubble, and a base of concrete was prepared for the tramway blocks, 1 foot 10 inches wide and 6 inches thick. The tramway blocks were then turned over and were fixed with Portland cement to the concrete bed. In a few instances, where the blocks had to be raised for laying water or gas pipes, it was found that they had stuck to the concrete beneath, and had to be actually cut away.

The cost of these two sections was—

	Fig. 2.	Fig. 3.
	Cwt. qrs. lbs.	Cwt. qrs. lbs.
Weight of cast-iron blocks, per lineal yard	3 2 14	2 3 0
	£. s. d.	£. s. d.
Cost of cast-iron blocks, per lineal yard .	1 5 4	0 19 0
Cost of concrete for filling and foundations, per lineal yard	0 4 8	0 3 3
Cost of laying blocks, per lineal yard . .	0 2 6	0 2 3
Total cost per lineal yard . . .	1 12 6	1 4 6

Such a road was, of course, contrary to all preconceived notions. Though elasticity had been constantly advocated, this road was thoroughly rigid. The blocks, once laid, remained there. At first

tie-bars were used, but it was found that they were not necessary, because the blocks could not be got to stir even when it was required to move them. The first part of the tramway had been laid seven years. Shortly afterwards the price of iron rose so rapidly that he ceased to think about the matter; but when the subject was about to be brought before the Institution he wrote to Mr. Deas, and received the following particulars:—From one hundred to one hundred and forty railway trucks went over the busiest part of the tramway daily, which was equal to a vehicle twice the weight of a tramcar passing every five minutes. He had inquired whether any regular railway locomotives had passed over the line. The reply was that none had done so; but that contractors' locomotives constantly passed, often dragging heavy loads upon bogies to the 60-ton crane. The highest speed of the railway vehicles was about 5 miles an hour, and of the street lorries 6 miles an hour. The tramway was chiefly designed for street or dock lorry traffic, which in Glasgow was very heavy; and it was a noteworthy circumstance that, if horses had to turn off the tramway, they always went back again of their own accord. The tramway was made of cast iron; he had therefore asked Mr. Deas how many blocks had been broken, and the reply was, "Not one." The blocks were ordinarily cast in 5-feet lengths. It was originally expected that in order to get them to lie steady 10-feet lengths would be required; but it had been found unnecessary to increase the lengths, because the blocks never showed any signs of motion. About six years ago 3 or 3½ furlongs of the same kind of tramway, for flanged vehicles only, had been laid in the Glasgow Corporation gas yard, and the manager reported that it had worked very well and occasioned no trouble. The edges had little notches ½ inch wide cast in them, at intervals of 3 or 4 inches, for the use of vehicles crossing the road; and he feared that there might be fractures from that cause, but none had occurred. The only thing beginning to need repair was the granite horseway between. In addition to the tramway along the street, two double lines were laid across the thoroughfare, to obtain access to a railway yard, and the whole of the ordinary traffic along the river-side passed over them, but no complaints had been made of horses falling down. The cost of the tramway had been £3,500 per mile, or £1,000 more than ordinary tramways, if made so as to accommodate unflanged, as well as flanged, wheels. For flanged wheels only, the cost was about £100 per mile more than that of other types of tramway. The latter, however, were now costing £250 a year per mile for repairs, although they were only beginning to

get rickety, and no one could say what their condition would be in three or four years. He might add that the traffic on the Broomielaw tramway was incessant.

Mr. W. MARTINEAU said his connection with a large tramway car building firm had given him opportunities for becoming acquainted with what had been done in the construction of tramways in England and abroad. In England and Scotland the ordinary 4-feet 8½-inch gauge had been almost universally used. In Ireland the Irish railway gauge of 5 feet 3 inches had been followed, but he thought it was a little too wide for the convenient working of tramways. In a few other countries a narrower gauge had been adopted. Thus the Madras tramway was on the mètre gauge, and the same gauge had been laid in Rome. In the Isle of Man and in one case in Ireland the gauge was 3 feet. He thought there was no objection to the narrower gauges; but whatever the gauge might be, it was of the utmost importance that it should be maintained throughout the whole length of the tramway. Nothing contributed more to the destruction of tramway wheels than a line being a little out of gauge; and wherever wheels were found to wear unduly, the engineer might be almost certain that some part of the line had not been truly laid. He thought that cross sleepers were advisable, and indeed necessary for the preservation of the width throughout.

The weights of the cars and wagons employed on different systems were shown in the following table:—

WEIGHTS of CARS and WAGONS CONSTRUCTED by the STARBUCK CAR and WAGON COMPANY, LIMITED.

Carriages—						Cwt.	qrs.	lbs.
London car to seat 22 in and 24 out					weight	49	3	0
Hoylake	„ 22	„ 24	„		„	46	3	7
Birkenhead	„ 22	„ 24	„		„	47	1	14
Oporto	„ 20	„ 20	„		„	40	2	0
Middlesbro'	„ 16	„ 16	„		„	34	0	0
Naples open car, with 5 transverse seats to seat 20					„	21	1	20
„ car to seat 12 inside only (with partition)					„	26	3	14
„	„ 16	„			„	34	0	0
Brussels	„ 16	„			„	34	0	0
Middlesbro'	„ 14	„			„	24	1	0
Sheffield	„ 16	„			„	29	0	0
Leeds	„ 18	„			„	31	0	0
Tramway goods trucks—								
Pernambuco wagon					weight	29	2	11
Oporto open goods					„	27	1	0
„ covered goods					„	32	1	0

N.B.—The weights given above include wheels and axles.

It would be seen that the weights varied from 2½ tons for a full-sized car carrying forty-six passengers, to as low as 24 cwt. for a light one-horse car carrying fourteen inside. Some heavier cars weighing over 3 tons (not mentioned in the table) had been made for Russia. They had wrought-iron under-framings, iron panels, and elliptic springs. The Author had stated that india-rubber springs might be got to endure every climate, but it had been found that they would not bear the extreme and lasting cold of a Russian winter, for which steel springs were indispensable. The Russian engineers also preferred screw brakes. These things, of course, rendered the car much heavier. Fortunately, St. Petersburg, where tramways were largely developed, was level, otherwise great difficulty would be experienced in dragging the cars. Light one-horse cars had been introduced in England, principally at Sheffield, Leeds, and Leicester; and abroad, in Naples, Oporto, Antwerp, and Brussels; and he thought they would be brought into extensive use. An eminent French engineer, in reporting to the Municipality of Paris about a year ago, stated that the essence of a tramway was to keep up a continuous flow of traffic, so that, as far as possible, a car should always be in sight; and that could often be much more economically attained by a light one-horse car than by heavier cars with two horses. With regard to the duration of cars, the Author stated that cars had run in the United States for twenty years. It should be known that those cars had no top seats, for there could be no doubt that the heavy weight of a top seat, with a number of people on it, did, in starting and stopping, strain the framework of a car, and that therefore cars without such seats lasted the longest. American wheels combined extraordinary hardness in the tire with great toughness in the body of the wheel. There were not many wheel-making firms in America, and the procedure of each firm was to a certain extent secret. A quality of iron was secured which admitted of crystallisation and chill entering a remarkable distance into the fibre of the iron, and a careful system of annealing was adopted after the wheels were cast. The question of the construction of tramways had long since been discussed. He had a plan for tramways for the whole of London, dated January 1851; also a sheet of tramway sections dated 1854, in which most of the points as to the structure of the permanent way of tramways were laid down. He had attended several trials of steam tram-cars, and it appeared to him that on a level line little difficulty was experienced. The limit of incline, which the Author had put at 1 in 30 for tramway rails laid in England, was probably reached much earlier than that. An

engine was required which would start without hesitation on the gradient, whatever it might be, in all states of the weather; and in order to secure that result, in any particular case, the amount of adhesion was an absolutely known item in the calculation. If the amount of adhesion implied a weight on the wheels greater than the rails would properly and economically carry, the limit was reached, and either heavier rails must be laid or the use of steam be abandoned. The use of steam in each case must be determined by the strength of the line to carry the weight of an engine necessary to work on the steepest incline.

Mr. E. A. COWPER was surprised that an opinion should have been expressed in favour of iron rails over steel rails for tramways. Not only were steel rails stiffer and stronger, but they were harder. A great deal of grinding or wearing of the rails was caused by the grit and sand on the road; and a soft rail would necessarily suffer from that action more than a hard one. Any one who had observed the grinding action of emery would have noticed that it made a much deeper cut into soft iron than into steel. Steel, therefore, was undoubtedly the right thing for tramway rails.

Mr. E. PERRETT observed that the Author had not mentioned what he considered to be the immediate cause of the rapid loosening of the spiked rail from the sleeper. It was impossible to suppose that the mere passage of a 5-ton car over a 30 or 40-lb. rail spiked down could loosen it. The cause was rather to be sought in the extremely unmechanical construction of the car. An ordinary London street car weighed when loaded about 5½ tons, was 22 feet in length, and was balanced on a 5½-feet or 6-feet wheel base in order to get round a sharp curve. Oscillation was soon set up, which this wheel base was unable to control; and that had been the chief cause of the withdrawing of the spikes, and the abandonment of a rail which was otherwise cheap and good. He did not think that any rail would long remain secure without a more extended wheel base to the cars running over it. He was aware that cars with six wheels had been tried, but the additional weight was too much for the already overtaxed horses. When steam was introduced, together with suitable rolling stock, that difficulty would be overcome. In the cars with six wheels the wheel base was made flexible, the central pair of wheels having power to travel sideways across the car. He disagreed entirely with the conclusion of the Author that detached engines and cars were superior in nearly every respect to combined engines and cars. Leaving out of consideration such qualifications as absence of smoke, steam, or noise, which both kinds of machines might or

might not have, the great requisite for a tram passenger car for use in and about towns was handiness. In this was included, power, to run either end first without turning or bringing the engine round, to ascend a steep gradient, to stop quickly in going down, to take sharp curves, and also, what had apparently been lost sight of, power to steer. The detached engine failed in all these important particulars, the combined engine need not fail in any one of them. In the case of some combined cars the driver had only to walk from one end to the other on the return journey. With reference to ascending a steep gradient, it might be all very well to increase the weight of an engine from 3 tons to 5 tons to give the necessary adhesion, but that was not the proper way of overcoming the difficulty. A heavier engine than was otherwise necessary to do the work was a faulty machine. A detached engine of 3 tons was not sufficient to draw a car of 5 tons up a moderate gradient. To drag cars on ordinary lines 20 or 30 lbs. to the ton was necessary, and on curves the traction amounted to 50 or 60 lbs. to the ton, so that the limit of gradient was soon reached by a detached engine and car, and to connect the moving parts of the engine to the car wheels to gain adhesion was making a combined car of the worst kind. The disadvantage alluded to by the Author, of an engine drawing a 22-feet car with 8 feet overhang round a curve, was obvious. Suitable cars could be made to be pulled by an engine, but that did away with the argument for the use of detached engines, namely, the possibility of using up existing stock. As regarded steering power this was of no moment with horse cars as the horses gave the necessary list to the cars, but a locomotive must have points and attendants at the branches, whereas with the number of wheels necessary for a combined car, steering could be easily effected. The alleged advantages of a detached over a combined engine were: the power of using up old stock, the power to take two cars on an emergency, greater safety to passengers, and cheapness or facility of repairs. The first was no advantage in new tramways; and in the case of old tramways, especially where outside passengers were carried, he had been informed that the existing cars broke up so rapidly, owing to their unmechanical construction, that no company would care, even if it could afford, to replace the existing stock by steam stock any faster than the existing stock broke up. Independently of that, the existing stock was not fit for steam traction, being far too light. The power of drawing two cars was not peculiar to a detached engine; a combined engine and car was still more capable of taking an additional car. A detached engine was considered by some safer for pas-

sengers, but he did not remember any instance in which a locomotive boiler had exploded whilst running. The Author stated that when a combined engine was under repairs £800 would lie idle. That might be so for slight repairs, but it amounted only to this: the cost of a detached engine was about £600 and of an ordinary car about £200; the cost of an engine and car combined was £700; so that there was a saving on the original cost; and in the case of repairs to the engine the difference in the value laid up was only that between £600 and £700, or £100. But if a combined engine and car were properly made, for extensive repairs the engine could be easily detached and another substituted, in which case the amount lying idle would only be £200 or even less. He had constructed a car for experimental purposes, with a fixed wheel base of 4 feet, to which the power was attached, set on a frame that could be easily removed from the main frames of the car. A two-wheeled Bissel bogie at either end gave a 17-feet wheel base. It was capable, nevertheless, of running round a curve of 35-feet radius, and by a steering arrangement at each end, it could be taken on to the road or off the road, or on the branches, without the slightest difficulty; and was free from oscillation. There was a small boiler at each end, connected together, the object being to distribute the weight, and also that the driver might stoke the boiler behind him, whichever way he was going, the two boilers being connected, he knew what was going on in both. The weight of the car when loaded was 8 tons, of which 5 tons were on the driving wheels and available for adhesion. He believed the car fulfilled all the conditions required in a passenger car. Where a tramway was like a light railway, the vices of a detached engine were less apparent, and it might be made suitable for the work, but for ordinary passenger traffic he thought a combined car possessed every advantage.

Mr. C. B. KING considered that the car just described would not satisfy the requirements of the public. In Paris, one line of tramways, 5 miles long, was worked entirely by an ordinary locomotive engine, with a special arrangement to prevent the emission of steam and smoke, and it did its work well. He was informed that the cost of steam, as compared with horse traction, was at present as $5\frac{1}{2}d.$ to $7\frac{1}{2}d.$, but this was subject to variations as coal and fodder altered in price. The advantage of a combined car in obtaining adhesion had been mentioned. He, however, preferred a light detached engine. In order to increase the power of adhesion of such an engine many arrangements had been tried, the most effective of which was Holt's system adopted by

Messrs. Merryweather. The engine was coupled to the car by an endless chain, passing round a chain pulley on an axle of the engine, and likewise round another chain pulley on one or both axles of the car. These pulleys were disengaged on the axles by self-acting gear when the extra adhesion was not required; in some cases this chain was driven by an independent auxiliary cylinder, which only worked when going up inclines. This cylinder had a much higher piston speed than the locomotive cylinders, so that a 5-ton engine could work an ordinary car up inclines of 1 in 12 and 1 in 14 in all weathers with ease. He had seen an engine of $3\frac{1}{2}$ tons weight, on one of the North Metropolitan tramways, ascend an incline of 1 in 27, and go round a curve of 35 feet radius, with a car and fifty passengers. He was afraid that Mr. Perrett's car would not pass the regulations of the Board of Trade, one of which was that passengers were not to pass and repass the motive power. He had been informed that on the Paris line the public were at first much terrified at the prospect of an engine going along the road at a speed of 15 miles an hour; but after an experience of six or eight months the idea of returning to the old modes of conveyance had been abandoned. It was found that ordinary vehicles never got on the line, always carefully avoiding it.

Mr. E. PERRETT explained that the Board of Trade officials had seen the drawings of the car he had described, and offered no objection to the arrangement.

Mr. WALTER HANCOCK remarked that his uncle (whose pupil he had been) had worked at the subject of steam carriages continuously from 1824 to 1836, and had made eight or nine carriages designed to compete with carriages on common roads. He was obliged to allow for the enormous tractive force required, and for the vicissitudes of the roadway, so that the power of his engines was greatly in excess of that required on tramways. The engines were of three classes. One was a small engine, with $3\frac{3}{8}$-inch cylinders, making 150 strokes per minute, for a carriage conveying four persons; another was a 9-inch cylinder engine, with 100 lbs. pressure of steam per square inch, making 100 strokes per minute, for a carriage conveying ten or twelve persons; and another was a 12-inch cylinder engine, with a length of stroke also of 12 inches, for a carriage to take twenty-four to thirty passengers. This was prior to the great improvements in steam engines, so that the consumption of fuel would now be considered enormous. In twenty weeks' continuous working of the "Automaton," the largest engine when making 100

revolutions per minute, to go 10 to 12 miles an hour, over a distance of 4,200 miles, 700 journeys, and carrying 12,700 passengers, 55 chaldrons of ordinary gas coke were used, equal to 20 lbs. per mile. The total cost was 2½*d.* per mile for carrying only half the number that an ordinary tram carriage would carry at a cost of 1*d.* per mile. The engines were made, as all old engines were, with defective valves, it being long before the improvements by Dewrance and others in 1837 and 1838, by which the consumption of steam had been much diminished. Not only was it necessary to carry more coke and more water, but the strength and weight of the carriage were increased, its weight when loaded being from 4½ to 5 tons. In consequence of these experiments a parliamentary committee was appointed, and in their report in 1831 the belief was expressed "that the substitution of inanimate for animate power, in draught on common roads, is one of the most important improvements in the means of internal communication ever introduced. Its practicability they consider to have been fully established; its general adoption will take place more or less rapidly, in proportion as the attention of scientific men shall be drawn by public encouragement to further improvements."[1] Here were none of the timid fears and cautions to be found in the reports of the more recent committees.

Mr. E. CHADWICK, C.B., thought that sanitary science might put in an appearance in connection with the subject of tramways. It had long since been apparent that every means of cheapening transit, and facilitating the distribution of the population, tended to diminish overcrowding in urban districts. If things had remained as they were, there might now have been in the metropolis and other urban districts a double and even a threefold population heaped up on the old areas; and however good the sanitation might have been, there would certainly have been increased death rates. His colleagues on the Metropolitan Sanitary Commission had before them the evil of overcrowding. Stone trams were suggested, of which various examples existed, reducing the horse traction more than one-half; but there were obstacles in the way, chiefly administrative, arising from the fact that all the radii out of London were split up into different parochial jurisdictions, there being one for almost every mile of road. This division had added largely to the expenses of all the tramways, and one director had informed him that the dividends of his line had been almost

[1] *Vide* "Report from Select Committee on Steam Carriages; with the Minutes of Evidence and Appendix." Folio, London, 1831.

taken away by the exactions of the separate jurisdictions. He would suggest that accounts of the expenses of different lines should not only contain the engineering costs per mile, but the cost per vestry. It would be seen by the evidence given before the recent Tramway Committee, that in that respect there was an enormous difference in favour of Paris, in consequence of the unity of management and scientific administration existing in that capital in having only one authority to work through, and that a scientific authority acting with knowledge, instead of obstructive from ignorance and prejudice. He still thought that the granite tram, as adopted in Italy, possessed a prodigious advantage; but a well-laid asphalt might take its place, being only half the expense, and double the wear. The asphalt tram had the advantage over the granite tram, and indeed over the iron tramway, in the absence of joints, and when properly laid there were no jolts. Being, as it were, in one piece from end to end, there was little or no resistance, so that it was more favourable to the use of lighter locomotive machinery and carriages, than granite or iron. The tenacity of the Neuchatel asphalt, as displayed in Cheapside, with its traffic of sixteen thousand vehicles daily, was marvellous. It had been laid down about seven years, and had apparently lost little weight, and was only compressed by about one-third, and might have a wear as long as that in Paris, which was seventeen years. The wear of the ordinary granite trams at the East of London, with much less traffic, was stated to be about 1 inch a year. Much of the first asphalt roadway was defective in being wavy and undulating from being badly laid. He had been led to believe that the saving of tractive force on asphalt roads was about the same as that on granite tramways, or about one-half, as against common macadam roads, but he had later assurances that the saving on well-laid asphalt was fully two-thirds of the tractive force required on the common roads, enabling a proportionate saving of engine power on them. The obstacles that stood in the way of the application of the principle of the tramway were chiefly the divided jurisdiction of the roads and the want of science, some additional outlay, and no interest, created by a monopoly, such as was given by the iron tramway; the asphalt tramway being like the granite tramway in Northern Italy and this country, open to all private vehicles, which was, in reality, its recommendation. He had been at pains to ascertain the comparative wear of the road by the wheel and the horse, and he thought he could state it as a constant, that whilst the wear by the horse foot was as one, the wear by the wheel was as two.

Hence the tram he proposed would take away two-thirds of the common road wear. But it would have great importance in saving the wear of common carriages, as well as of locomotive machinery of all sorts. Locomotive machines were at present excessively heavy, as were carriages, to withstand the roughness of the roads. He did not mean to say that for roads of slight traffic, and for bye-ways, wheel tracks of cheaper construction than those he proposed might not be had. But a great object, as he conceived, for the attainment of economical transit was to get hardened wheel tracks open to all traffic.

Mr. HOPKINS said it was evident that the time was not far distant when some mechanical power would be introduced on tramways. At present the only motive power at all complying with the requirements of the Board of Trade was steam and compressed air. Steam engines, made by Messrs. Merryweather, were running in Paris at the present moment; steam engines were also running in Brussels. Mr. Hughes had also succeeded in producing an engine which had given great satisfaction; and he had likewise seen an engine by Mr. Perrett which had considerable merit, but it had not been brought before the committee of the House of Commons. Mr. Scott Moncrieff's engine, worked by compressed air, had been running successfully at Glasgow; and M. Mékarski's compressed-air engine in Paris had worked admirably. They worked generally with a pressure of 4 atmospheres, and could run easily at 20 miles an hour, stopping within a short distance. In ascending gradients the action was perfect; the engine was stopped purposely, in the middle of an incline, about 1 in 20, and then ran down and ascended it again. The authorities were labouring under great disadvantages with regard to charging the cylinders, because they had only temporary engines for compressing the air.

Mr. SOUTTAR, in reply upon the discussion, said, with regard to the complaint that his Paper contained no estimates, in the first place he had felt that estimates were to some extent misleading, and in the second place he had written a chapter on the subject, but had eliminated it as the Paper was getting so long. He regretted, however, he had not mentioned that a tramway would cost practically the same whatever system was adopted, and that it was a question of condition and not of system. In every well-constructed tramway there were three constant quantities, the concrete, the paving, and the rails, making more than three-fourths of the total expenditure, the remaining fraction being represented by the longitudinal bearing, fastener, &c. Comparing

tramways with timber bearings together, the cost would be practically the same, or a little more where cross sleepers were used instead of tie-rods, and comparing these with tramways having iron bearings the latter would naturally be more costly. In Mr. Kincaid's system, with chairs 3 feet apart, the cost was, at the present price of iron, about the same as that of timber. The longitudinal bearing for the Manchester tramway was in the proportion to a timber bearing of 256 lbs. of cast iron to 6 lineal feet, by 6 inches by 4, of timber, with an allowance for cross sleepers and fastenings, the ratio being practically as 3 to 1. Mr. Lynde had stated that "the cost of this system varied from about £2,000 to £2,300 per mile, according to the weight of metal and depth of paving used." The remark illustrated what the Author had said about the misleading nature of estimates. For, taking the amount of metal required for the work, at market prices it would be found that the margin could only cover the labour of excavating, laying the line, and reinstating old paving. The estimate neither included concrete under the tramway nor paving, and the rail was only 40 lbs. to the yard, instead of from 50 lbs. to 60 lbs., as usually adopted. Mr. Beloe had fairly set down the price of a properly constructed tramway at £4,500 per mile, and with this price Mr. Lynde's system would appear to contrast most favourably; the fact being, however, that Mr. Beloe gave the price of a complete tramway, whilst Mr. Lynde gave the price of half a tramway. It could not be too clearly understood that the cost of a tramway was only slightly affected by the particular system under which it was laid, but materially by the weight of rail and quality of paving and concrete that the circumstanees rendered advisable. Mr. Fowler's preference for a rail supported on a series of hard points, instead of on a continuous bearing, seemed incomprehensible, as well as his preference for iron over steel. Mr. Cowper's remark, that the grinding of the rails caused by grit or sand was better resisted by steel than by soft iron, was justified by experience. Mr. Fowler was under a misconception with regard to the rail which the Author had introduced. There was no space between the fastenings, the timber was the extreme width of the rail, and a little piece was gouged out into which the fastener sank. The sinking of the pavement on the Glasgow tramways, noticed by Mr. Beloe, was probably due to the fact that an unnecessary quantity of sand, 2 inches, was laid under the paving, and not to any failure on the part of the bituminous concrete. The tramway described by Mr. Rapier would be useful as a means of reducing the friction of heavy vehicles,

travelling at a slow pace, just as rows of flat stones were useful for that purpose. There were, however, points in the system which would render it unsuitable under ordinary circumstances, where a quick, rattling motion had to be endured; and there was nothing in its design calculated to diminish the cost of repairs, as compared with other tramways. Mr. Lawford disagreed with the conclusions on the subject of asphalt, and quoted an instance of asphalting in London. The piece referred to was done under the Author's superintendence, and he would therefore gladly defend it; but the fact mentioned, that it had been found necessary to put stone on each side of the rails, spoke for itself. Mr. Lawford said he should like to see a street tramway laid for £1,500 per mile, and then gave details of a tramway he had laid for less than £1,400 per mile. Of course a tramway could only be laid at the price mentioned under exceptionally favourable circumstances, and in the lightest possible manner. Mr. Perrett would find that "the immediate cause of the rapid loosening of the spiked rail from the sleeper" was the breaking of the spikes at the neck. Perhaps the construction of the car had something to do with this; but the Author thought it would generally happen when the rail became so worn that the wheel flange could touch the bottom of the groove. Mr. Perrett had contrasted some of the arguments in favour of a combined engine with some of the arguments in favour of a detached. For the former he claimed adhesion, handiness, and steering capacity. There could be no doubt that the combined engine was superior in the matter of adhesion. On the second point, the detached engine would be made handier to work than the combined engine in everything except shunting. On the question of steering there was little to say. Steering gear would complicate the car, and would be useless at night. It was questionable if the power of steering would be of any practical value. In dealing with repairs, Mr. Perrett had misunderstood the Author. In saying that a slight accident would cause £800 to lie idle, an accident to the car was meant, not to the engine. Whilst the Author felt that the question might be still more fully tested with advantage, he thought that every day showed more clearly that the detached engine was the tramway engine of the future. On the question of pneumatic cars, whilst recognising the difficulties in the way, the Author was scarcely so hopeless as some of the speakers. He was sorry that Mr. Scott Moncrieff had found it impossible to be present at the discussion, especially as he believed an arrangement had been concluded which would enable the method to be fairly tested in the course of the next year.

Mr. STEPHENSON, President, said he had hoped that more distinct information would have been elicited in regard to a better class of engine. The improvement of the rail would take place in the course of time. Some years ago he had occasion to examine the details of one of Mr. Grantham's engines, and he was strongly of opinion at the time that a separate or detached engine would be the best. He had carefully watched the progress of the engines, and although he was not prepared to give the cost of working, the more he had gone into the subject the more satisfied he was that a detached engine would ultimately come into use. He had no interest in any of the engines, and his opinion was, therefore, an unbiassed one. Mr. Longridge had objected to the detached engine on the ground that it had only its own weight to deal with for adhesion; but if he had looked at the matter more closely he would have seen that a detached engine could be made to take certainly half the weight of the carriage. It might be placed in the middle of two carriages, one-half of each carriage resting upon it, by a joint devised for the purpose. He was not prepared to admit that the old stock could be guaranteed for the proposed new tramways. He was glad that the subject of tramways had been discussed; and every one would desire that the sufferings of the horses might be relieved, even if the pockets of the shareholders were not filled to the extent they were at present.

Mr. DEACON remarked, through the Secretary, that for many years he had given attention to the subject of street tramways. Before making any recommendation with respect to the proposed reconstruction of the existing lines in Liverpool, he had visited all the more important tramways in this country and many of those on the Continent, and had studied the available literature on the subject. He had endeavoured to approach the question with a mind unbiassed by railway practice, or by the particular forms of street tramway which had in some degree grown out of that practice. His investigations had been completed with a strong conviction that no existing system of laying street tramways was entirely suited to the exigencies of the irregularly built and crowded streets of the principal cities and towns of this country. He thought inventors had not apprehended the true nature of the difficulties to be overcome before municipal authorities and the owners of ordinary vehicles could fairly be expected to approve of tramways. The inconvenience to ordinary vehicles, caused by cars having no power to move aside, was very great, and though not inevitable in a mechanical sense, it must be admitted as a necessary

evil when street tramways were allowed at all, for nothing but confusion would arise if ordinary vehicles had the power to cause heavy tramway cars to leave the rails. But the evils of street tramways were due not only to the inevitable tramway car, but to the existence of the permanent way. This permanent way involved, for each line of tramway, four longitudinal joints between materials of different hardness. It was well known to be impossible, in the ordinary mode of paving, to prevent the formation of a groove wherever a longitudinal joint existed, even when the materials on both sides of the joint were the same. It was still less possible when the materials were of different natures. If, however, a course of setts were sawn in halves parallel with the street, and the setts were so bedded that the sawn joint remained close, the bearing surface of the setts was not reduced and no greater wear took place at the joints than elsewhere. Again, if near the line of such a joint the upper edges of adjacent setts touched each other at the transverse joints, there would be more bearing surface at and near the longitudinal joint than elsewhere, the intensity of pressure from traffic would be reduced, and instead of a groove forming, the wear would be actually slower than elsewhere. Having applied the same principle to the courses of setts immediately adjoining tramway rails, his expectations had been completely realised, after seventeen months' trial, under the most severe conditions.

During the reconstruction of the tramways in Liverpool the streets in which they were laid were being repaved and provided with new foundations from curb to curb. The vehicular traffic was entirely suspended, the old foundation was removed, and a bed of Portland cement concrete was laid and finished with a perfectly smooth surface, which was allowed to stand for ten days or more before the paving was commenced. Directly upon this the longitudinal sleepers rested. The rails were held down by bolts passing through the sleepers to plates beneath the concrete at every 3 feet, and these bolts could be tightened at openings in the sides of the sleepers. The setts next the rail were of durable stones, and were carefully dressed in such a manner that, unlike the other setts which were bedded upon $\frac{1}{2}$ inch of sand, they rested firmly upon the concrete, while their edges touched the edges of the rails, and their sides near the rails touched, or nearly touched each other. Being laid alternately, and accurately gauged in all dimensions, they could be drawn and replaced with similar setts without disturbing the surrounding pavement. The joints of all the setts were filled with gravel from $\frac{1}{4}$ to $\frac{3}{8}$ inch in diameter, among which a mixture of boiling pitch and creosote oil was poured.

It was generally known that in streets of moderate traffic the wear of a tramway rail, caused by the tram-cars, was insignificant in comparison with that due to the ordinary traffic. In the rail now in general use, 4 inches wide, a breadth of $1\frac{7}{8}$ inch was covered by the tread of the wheel, $1\frac{1}{4}$ inch being occupied by the groove, while the remaining width of $\frac{7}{8}$ inch was only useful for strength and as a guard for the flange of the wheel and the pavement of the horse track; but this extra metal gave only lateral strength, which was not required, while the whole surface, whether superfluous or not, was constantly being worn down by the ordinary traffic. It was therefore obviously important to make the rail as narrow as possible. A reduction of width would also lessen the danger to horses, and the incentive which the drivers of ordinary vehicles felt to occupy the rails, and thus wear them and the adjoining pavement unduly. If the groove were placed in the centre of the rail and the tread on both sides, not only would the pressure be better distributed, but the whole surface might be utilised, and with the same total width of tread the width of the rail might be reduced from 4 inches to less than $3\frac{1}{8}$ inches. Where, therefore, as in the case of street tramways, a groove was desirable, it was difficult to understand why it had never been placed in the centre. Mr. Souttar had referred to the central groove which Mr. Deacon had adopted, but had not stated the reasons for its adoption, though he had expressed fears that the friction would be greater, owing to there being no escape for mud or gravel; that the tendency of cars to run off on curves would be greater; and that the centre flanges on the car wheels would be weaker and more liable to chip off than the side flanges. The mud difficulty was common to all grooved rails. In the side-grooved rail, if there was enough mud to be pressed out, part escaped on the free side, part under the tread of the wheel. In this case it had twice as far to travel before it was liberated from the rail as in that of the central groove, where it all passed beneath the two half treads; so that for the same quantity of mud the two cases were almost similar. It was usual to remove mud periodically by an instrument designed for the purpose, and in order to avoid friction due to the squeezing out of mud during the intervals there was no objection to the groove being made deeper than usual. The Author of the Paper had given no reasons for his belief that the cars would run off the line more readily because the grooves were central; and as the flanges of the wheels were not altered in depth there was no mechanical reason why they should do so. The Author thought a side flange would be stronger than a central

flange; but this was opposed to the known conditions of strength in projecting portions of castings. In cast-iron wheels the central flange with fillets on both sides would certainly be stronger than the side flange with a fillet only on one side; while any method adopted in the case of the side flange, to prevent it from becoming brittle by too deep chilling, was available in the case of the central flange.

In straight lines the central groove might with advantage be reduced in width. The flanges of tramway wheels were generally only $\frac{1}{2}$ inch wide, while the groove of the rail was more than $1\frac{1}{4}$ inch. He believed that great extra friction, due to transverse motion of the car, resulted from this; but the wide groove was stated to be necessary to hold mud. This might be a good reason for deepening the groove, but it could not, he submitted, be a good reason for widening it. Some allowance must be made for defective gauging of wheels and rails, but his own observations had led him to believe that $\frac{3}{4}$ inch for the width of a groove was ample. With such a central groove a rail $2\frac{1}{2}$ inches wide would have greater bearing surface than the present rails 4 inches wide.

Among the most expensive parts of a tramway to maintain were the points. Their chief cause of weakness arose from the want of sufficient area of tread when a wheel approached the point and bore upon its narrow surface only. This surface was rapidly worn down, and the wheel, on coming in contact with the tread of the rail beyond the point, had to mount on to it, and thus produced the inclined plane noticeable in all tramway points after a short period of use. The central groove and flange with the double tread obviously removed this difficulty. In Liverpool he had, unfortunately, had to consider the fact that the side-flanged wheels on the old lines must at first run upon the reconstructed portions also, and the width of the rail had therefore only been reduced from 4 inches to $3\frac{1}{4}$ inches.[1] For rails of the usual width the recessed dog-hook fastenings used by the Author had obvious advantages over the projecting dog-hook fastenings; but if used with the narrower rails, which he thought desirable, they would involve a greater reduction of the base of the rail and of the width of the sleeper than was consistent with stability. Another objection to such comparatively light

[1] Since this was written about 1,000 yards of the most recently constructed tramway has been opened to traffic in Liverpool. The side-flanged wheels are now running in a perfectly satisfactory manner on the central-grooved rails, as well as upon the old side-grooved rails; but these wheels are being rapidly replaced with central-flanged wheels which, until the lines are entirely reconstructed, will also run on both kinds of rail.—G. F. D., Aug. 4, 1877.

fastenings was their greater number and consequent interference with the pavement before they could be reached.

Mr. H. HUGHES observed, through the Secretary, that the locomotive designed by his firm had been tried against a compressed-air engine at Glasgow. The former engine had two cylinders, each 6 inches in diameter, with a length of stroke of 12 inches; the average pressure in the cylinders being 50 lbs. per square inch; the distance run was 31 miles; the time occupied in the run five hours and one quarter, and the speed 6 miles an hour. The compressed-air engine had two steam cylinders for pumping, each also 6 inches in diameter with a length of stroke of 14 inches. The air was compressed to 350 lbs. per square inch; the average working pressure was 50 lbs. per square inch. The distance run was 12 miles, and the speed 6 miles an hour. The steam engine was nine hours in compressing the air.

He thought the reason why some engineers were favourable to an engine placed in a car was, that they underestimated the power required. It had been found that the weight of a well-constructed locomotive engine, with all proper appliances, and to be safe for a tramway journey, without taking in fuel or water, would be 6 tons, a sufficient weight for adhesion. But if such an engine were placed in the car, the total weight on the four wheels would be 10 tons, a load too great for many tramway rails. The separate locomotive was a simpler way of distributing the weights on the rails, and of extending the wheel base without diminishing the facility of passing round curves. Moreover, in all cars containing their own engines which had yet been designed, the wheels were not coupled, thus dispensing with the merit to which their inventor laid claim.

Mr. A. O. SCHENK remarked, through the Secretary, that in trying to find out the soundest mode of construction for the permanent way of street tramways, the probable substitution of mechanical for animal power, at no remote date, should be prominently kept in view. If this were effected, any defects in existing arrangements would be intensified, when the traction was obtained by the adhesion due to a concentrated load on two or more pairs of wheels. Under these conditions, the system, in which the rail was a mere bar laid flat, dependent for its stability on the permanence of the connections that united it with its continuous longitudinal support, must give way to a mode of construction better adapted to the new method of traction. In this arrangement the rails, under the action of passing loads, tended to slide upon the upper surface of the timber, but were resisted by the fastenings, these being thrown

into direct shear, in the course of time, and under the frequent repetition of this action worked loose. If this was the case now, what might be expected when a thrust of considerable magnitude was exerted along the rail, dependent on the weight on the driving wheels and the state of the rails? Further, the longitudinals had little lateral stiffness; and when it was borne in mind that heavy vehicles came on and went off at all angles, it would be seen that the paving adjoining the rails stood a poor chance of maintaining its position, being constantly under the action of severe shocks. The breadth, too, of the longitudinal being limited to 4 inches or thereabouts, the load was distributed over a small area. This also tended to shorten the life of the road. The system known as "Barker's," in which the longitudinals were of iron, possessed no advantage over wood in this respect, and, being of a harder material, would be more injurious to the foundation; while it also appeared to have disadvantages peculiar to itself—such as the impossibility of getting a uniform bearing between rough surfaces of wrought and cast iron over a continuous length, and the want of surface in the cotters which secured the rail to the support. It would seem, then, that the system which would be permanent must be one in which the above-mentioned defects were avoided or overcome. Mr. Beloe suggested that a good road might be made by a rail of common bar-iron section attached to cast-iron chairs, fixed in their turn to cross sleepers. Such an arrangement had been devised by him some months ago. To this plan the following advantages were attached:—(1) A rail was used which had vertical stability enough to carry the load without continuous sleepers. (2) The load was distributed through a broad-based chair over an area which was limited by considerations of expense. (3) A rail could be taken out and replaced without interfering with a single paving sett. (4) No iron fastenings were employed, and the evils of corrosion and enlargement of holes were avoided. (5) Less smooth iron was exposed on the surface of the street than in any other system. (6) The form of rail was adapted to the formation of points and crossings, and was well fitted for bending round curves limited in radius by the width and angles of streets. (7) It compared favourably in first cost with the best of existing systems, while in subsequent maintenance a considerable reduction might be looked for.

May 1, 1877.

GEORGE ROBERT STEPHENSON, President,
in the Chair.

The following Candidates were balloted for and duly elected:—HENRY BRAMALL, JOHN GEORGE THORNTON CODDINGTON, EDMUND BATTEN FORBES, JACKSON GOLDING, FRANCIS CHARLES LIDDELL, and ROBERT CHARLES PATTERSON, as Members; EDWIN WILLIAM BROOKING, ALEXANDER GRANT, ALBERT LATHAM, RALPH DANIEL MAKINSON LITTLER, Q.C., ARTHUR DANIEL MOULLIN, JAMES ALFRED MOUSLEY, WILLIAM PERCIVAL OAK, CHARLES HENRY SHORTT, Stud. Inst. C.E., JOSEPH JOHN TYLOR, Stud. Inst. C.E., and HORACE WILMER, Stud. Inst. C.E., as Associates.

It was announced that the Council, acting under the provisions of Sect. III., Cl. 7, of the Bye-Laws, had transferred GEORGE ARTHUR BIDDELL, JOSIAH HARDING, and RICHARD CHRISTOPHER RAPIER from the class of Associate to that of Member.

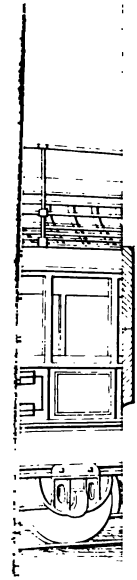
Also that the following Candidates, having been duly recommended, had been admitted by the Council, under the provisions of Sect. IV., of the Bye-Laws, as Students of the Institution:—CHARLES ALBERT BAYER, CHARLES WILLIAM BEST, EASTON DEVONSHIRE, THOMAS ARTHUR HEAD FORDE, and ARTHUR HILL.

The discussion upon the Paper No. 1,518, "Street Tramways," by Mr. ROBINSON SOUTTAR, occupied the whole evening.

BESSEMER STEEL.

Dr. PERCY exhibited some test pieces of mild Bessemer steel, received from Mr. F. W. Webb, M. Inst. C.E., now being made in large quantities for boiler and other purposes, at the London and North-Western Railway Company's works at Crewe. Likewise a rough turning off a Bessemer-steel crank axle, as well as some finishing

turnings taken off dry. These various specimens showed the uniform quality and reliability of the material, and that it was very homogeneous. That company had already seven hundred and fifty locomotive boilers of such steel. The rivet steel was found to possess a tensile strength of between 28 and 30 lbs. per square inch. Dr. Percy also drew attention to a piece of steel plate on which a large blister rose after coming through the rolls, and stated that the composition of the gas in the blister had not yet been examined.



1876.

HEEL Co

Fig: 22.

FOR AMERICAN RAIL.

Fig: 23.

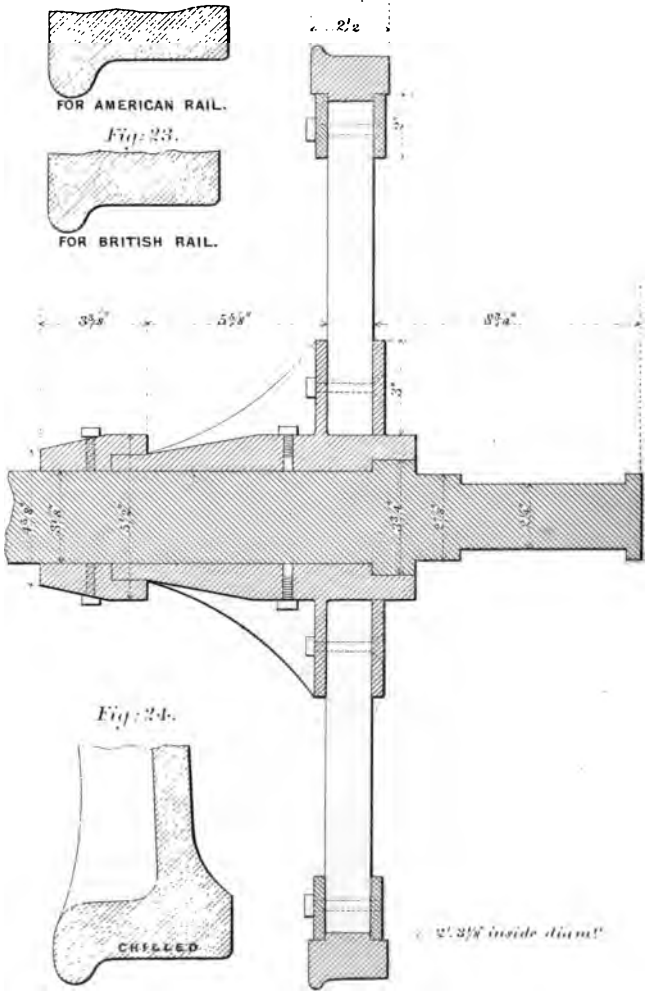
FOR BRITISH RAIL.

Fig: 24.

CHILLED

WHITNEY WHEEL.

Fig: 25.



REVOLVING CAR WHEEL.

Scale for Figs 21 to 24. ¼ Full Size.

3 6 9 12 Inches.

Scale for Fig. 25. 2 inches = 1 foot.

6 3 0 1 Foot.

HOE & CO'S KELL, LITH 40, KING ST COVENT GARDEN

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